Collision Analysis

Working Group (CAWG)

65 Main-Track Train Collisions, 1997 through 2002:

Review, Analysis, Findings, and Recommendations

July 2006

CAWG Final Report

Federal Railroad Administration

NOTICE

Although the Collision Analysis Working Group (CAWG) developed the findings, discussions, and recommendations contained is this report, the Federal Railroad Administration (FRA) takes sole responsibility for the final content. This report is issued under the auspices of the FRA.

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Dedication

The Collision Analysis Working Group (CAWG) dedicates this report to the memory of those railroad employees who died on duty. Recognition should never be lost that the real cost of main-track train collisions too often is human life. CAWG expresses its condolences to the families. The families should be aware that each collision review was handled with the utmost dignity and respect.

CAWG spent many hours studying the events of these collisions in developing its consensus findings and recommendations, which are aimed solely at eliminating future tragedies. The study of operating conditions, environmental factors, and behavior leading to these tragedies offered a unique opportunity to further improve safety and save the lives of men and women working in the railroad industry. The families who have experienced loss are assured that the lessons learned presented herein will save others their agonizing sorrow.

Acknowledgments

The Collision Analysis Working Group (CAWG) expresses its sincere appreciation to Allan Rutter, past Administrator of the Federal Railroad Administration, for proposing this important safety initiative: the review and analysis of main-track train collisions involving human-factor issues. The findings and recommendations made, based on the commonality of facts among collisions, will reduce and prevent the loss of life and injuries to railroad employees and passengers as well as damage to track, signal, lading, and equipment.

CAWG thanks Dr. E. Donald Sussman, past Chief of the Operator Performance and Safety Analysis Division of the John A. Volpe National Transportation Systems Center, US Department of Transportation/Research and Innovative Technology Administration, for his dedicated support of CAWG from its inception; and for many other human-factor, railroad safety contributions during his career at the Volpe Center.

CAWG recognizes that without the support of those listed below, and their organizations, this safety effort could not have occurred:

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Table of Contents

List of Figures

List of Tables

Data Appendix

EXECUTIVE SUMMARY

General

- Federal Railroad Administrator Allan Rutter proposed a Collision Analysis Working Group (CAWG) on June 4, 2002, to review and analyze main-track train collisions involving human-factor issues, and to make safety findings and recommendations should the facts warrant.

- Holding its first meeting on July 17-18, 2002, CAWG agreed to review main-track train collisions where human factor causes contributed to trains exceeding their authority by (1) passing a stop signal; (2) failing to comply with a signal requiring restricted speed; or (3) entering territory without a train order, track warrant, or direct traffic control authority. CAWG eventually selected 65 collision cases it believes contain enough information to find meaningful commonalities upon which to base collision-avoiding findings and recommendations.[1]

- Reviewing additional cases, CAWG believes, would unduly delay this collision-avoiding information from reaching the railroad industry. Many collisions were associated with human casualty both to railroad employees and passengers, a fact re-emphasizing the importance of timely prevention efforts.

- CAWG's review and analysis provides the railroad industry with an opportunity to re-examine its safety policies and practices based on the commonality of facts found in the 65 collisions. Taking note of the findings and recommendations will ensure reasonable precautions are being taken to prevent future such collisions.

- While working on this study, CAWG members, all serving as Switching Operations Fatality Analysis Group (SOFA) representatives, wrote and issued the report *Findings and Recommendations of the SOFA Working Group: August 2004 Update*, as well as releasing other switching operations safety information. CAWG members believed the recent number of switching fatalities required this effort.

Methods

CAWG's review and analytical methods consisted of:

- Including all cases meeting CAWG's selection criteria.

[1] Findings and recommendations in this study are based on commonalities of main track train collisions and not yard, highway-rail, or switching-operation collisions. Information contained in this report – including the Findings, Discussions, and Recommendations – is based solely on the review and analyses of 65 main-track train collisions occurring from 1997 through 2002. CAWG did not consider results of other investigations, reviews, and analyses of main track, or other types of collisions. CAWG results are specific to its data.

- Reviewing and discussing the operating practice and conditions involved in each case, and recording the information in the CAWG Database.

- Discovering meaningful and factual commonalities among cases.

- Making findings and recommendations based on these commonalities.

Collision 'Causality'

- CAWG developed an approach to collision 'causality' based on consideration of an often complex combination of rail system operating characteristics, conditions, and events. In determining causality, CAWG does not attempt to rank these factors, usually expressed as Possible Contributing Factors (PCFs). CAWG views causality as a web of interrelated factors. CAWG found that collisions do not result from chance, randomness, or bad luck, but from identifiable human-factor issues having remedies in operating practices.

  CAWG used the FRA's "Train Accident Cause Codes"[2] and its own defined codes as the basis for PCFs. As mentioned above, CAWG does not attempt to rank PCFs. Each collision was assigned as many PCFs as CAWG believed applied; however, the number of PCFs applied to a collision case did not go beyond the number necessary to capture the essence of the identified factors. CAWG avoided redundancies. Causal information not appropriately captured by a PCF was described in narrative form.

- Rarely are main-track train collisions the result of a single factor or cause. Review of the 65 collisions clearly establishes that most collision events are a combination of unrelated factors and deviations occurring at the same time, at the same location, and on the same train. Sometimes, these factors and deviations do not rise to the level of identifiable violations of operating rules, federal regulations, and/or industry standards; the greater the number of factors and deviations present, the greater the potential for a collision.

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[2] Contained in Appendix C, pages 1-11, of the *FRA Guide for Preparing Accident/Incident Report*. Federal Railroad Administration. 1997.

Harm

- Eliminating main-track train collisions will prevent enormous harm. CAWG wants to emphasize that although the 65 collision cases are 'accidents' in the sense physical damage exceeded the Federal Railroad Administration defining monetary threshold, main-track train collisions often are associated with human casualties. The 65 main-track train collisions resulted in 16 fatalities and 531 injuries. There were 14 employee fatalities and 128 employee injuries; 2 passenger fatalities and 403 passenger injuries. (One passenger collision in Placentia, CA, No. 53 [3], accounted for all the passenger fatalities and 163 passenger injuries.) There was $83,108,072 in track, signal, lading, and equipment damage. The most damage in one collision (Pacific, MO, No. 49) was $7,855,920, average damage being $1,278,586. There were 42 hazardous material cars derailed with four hazmat releases. Numerous other costs – direct, indirect, and opportunity – are associated with collisions, some calculable, some not.

Crashworthiness

- In its review, it was not the intent of CAWG to determine the crashworthiness of various locomotives; or relatedly the advisability of crews staying in, or jumping from, their locomotives given collision certainty. CAWG's review and analysis did, however, create data of potential interest to those involved in locomotive crashworthiness.

- CAWG went as far as it could in evaluating the locomotive crashworthiness issue. While having enough collision cases, CAWG needed more specific knowledge on the crashworthy features of different versions of the S-580 standard locomotives. CAWG hopes its effort establishes a baseline useful to other groups assessing crashworthiness. (Refer to Federal Railroad Administration's (FRA's) Website.[4])

- Additionally, CAWG believes its data and results should not influence a crew member's jump-or-stay decision. Such decisions are based on many variables, not the least of which is speed.

Findings and Recommendations

Note: CAWG Findings and Recommendations are based solely on its analyses of information contained in the 65 main-track train collisions occurring from 1997 through 2002.

CREW COMPOSITION AND EXPERIENCE

Findings and Discussion: Crew Composition and Experience

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[3] A CAWG No. is used to reference each collision case. A narrative summary of each case is included in this report, referenced by its CAWG No.

[4] On Federal Railroad Administration's (FRA's) Website: Click on 'Research and Development', then 'Research Reports'. Studies include DOT/FRA/ORD-02/03, DOT/FRA/ORD-01/23, DOT/FRA/ORD-95/08, and DOT/FRA/ORD-95/08I through 95/08V.

For freight trains, the conductor and engineer work as a team. One member points out situations that may have escaped the other's attention. In theory, this team concept should prevent collisions, but on occasion, collisions do occur. It is interesting to note of the six Amtrak collisions in this study, four involved one person in the locomotive cab. Two of four cases (CAWG Nos. 2 and 44) may have been avoided if a second crew member was present in the cab. A third collision (CAWG No. 3) possibly could have been avoided with an additional member. In all three cases (CAWG Nos. 2, 3, and 44) the engineer was not asleep. CAWG found, in fact, extraneous circumstances played a role in these three cases.

Based on a small sample of 33 trains, an estimate of the percentage of conductors who have experience between 7 and 22 years is 21.2 percent. CAWG has surveyed other industry sources that suggest the percentage of conductors (road and yard) in this experience range could be as high as 42 percent. Conductors with 7 to 22 years experience were not crew members of any violating trains. This suggests conductors in this experience range fulfill their role as additional safeguards in preventing collisions of the CAWG's criteria type.

Recommendation: Crew Composition and Experience
CAWG cannot conclude conductors with fewer than seven years experience are at a higher risk. However, when possible, an inexperienced crew member should be paired with an experienced crew member. Such pairing reduces the risk for the inexperienced crew member; but does not, as CAWG collision cases show in Table 5-4, increase the risk for the experienced crew member.

ALERTNESS

Findings and Discussion: Alertness
The methodology employed by CAWG in studying alertness includes: (1) defining alertness, for purposes of railroad operations, as to whether or not any action was taken; (2) examining available information concerning each crew member's sleep history, sleep period, work period, and time of event; and (3) consulting a sleep expert to independently evaluate CAWG's assessment of cases involving alertness.

After completing its review of each collision case, CAWG found that 19 of 65 cases – nearly 30 percent – involved alertness as a PCF.

Findings and Discussion: Alertness
Research indicates that degradation of employee alertness can lead to lapses in attention, slowed reactions, and impaired reasoning and decision-making that have been shown to contribute to accidents, incidents and errors in a host of industrial and military settings. Collectively, these effects have been described as 'fatigue' or 'impaired alertness'. CAWG adopted a data driven approach that focuses on observable behaviors of alertness, i.e., attention to and appropriate responses to one's surroundings rather than the less exact term fatigue that has various meanings for different people. Some collisions appear to

reflect impaired alertness since appropriate actions were not taken. Impaired alertness may be traced to a number of variables. Here the focus is on two main causes:

- Amount of sleep a person has had in the recent past
- Time of day

Many sleep experts believe the average person should obtain about eight hours of sleep per day to maintain peak alertness. Sleep induced impairments in alertness fall into two main categories. The first kind of problem occurs when a person does not get sufficient amounts of sleep each day, extending over a series of days. This produces what is called a sleep debt, a difference between the average amount of sleep actually obtained and the amount of sleep the person needs to maintain alertness. This may be caused by a number of factors including, but not limited to, problems obtaining sleep during off duty time (trying to sleep during the day or in an unfavorable environment), excessive work and associated work demands, such as commuting. Such chronic sleep debt factors may limit the amount of time to get sleep, compromise the quality of sleep or involved sleep disorder, such as sleep apnea. All of these factors can cause an accumulated sleep debt that can impair alertness.

The second kind of sleep problem occurs when a person has been awake more than sixteen hours since their last major sleep episode, called acute sleep debt. Ideally, people sleep eight hours a day and are awake for sixteen hours. Once the awake period exceeds sixteen hours, there is increasing pressure to go to sleep, which is reflected as a gradual loss of alertness and an increased potential for lapses. Problems from acute sleep debt can occur even when a person has been generally getting eight hours of sleep per day. A classic example of acute sleep debt can occur when a person awakens in the morning at 6 am after sleeping regularly from 10 pm to 6 am and does not take any naps prior to going to work in the evening. If work starts twelve hours after awakening and the work period is eight hours long, the person will have been awake for twenty hours at the end of the shift and may experience an acute impairment of alertness during the last half of the work period.

The time of day can induce problems with alertness because the human body has a biological rhythm that modulates alertness. People who are adjusted to day-time work are generally most alert during the hours from 8 am to 8 pm and experience impaired alertness between midnight and 6 am. This is called the circadian rhythm and is a property of many biological systems, including the brain. The exact timing of the rhythm can be changed by environmental factors. For example, when traveling to a new time zone, it can take many days for the rhythm to realign to the new time for sleep and wakefulness. If a person shifts from a day job to a night job, requiring sleep during the day, it may take many days or weeks for that person to adjust to that new routine. During the period of adjustment, the person will experience impaired alertness.

The two causes of impairments to alertness – sleep debt and time of day – are additive. A person working at four in the morning will be more impaired if also sleep deprived compared to a person at that same time who has been getting plenty of sleep and has been awake for only a few hours.

In summary, there are a number of variables that can impair alertness: chronic sleep debt, hours since awakening, and time of day. To determine the level of alertness impairment a crew member might experience, CAWG gathered evidence from numerous sources, including witness statements and interviews, event recorder data, and available work/rest histories of the crews. CAWG reviewed and analyzed each crew member's sleep history, sleep periods, work periods, and time of event.

After completing its review of each collision case, CAWG found that 19 of 65 cases – nearly 30 percent – involved alertness as a PCF. Realizing the importance of the alertness issue, CAWG asked Dr. Stephen Hursh, a sleep expert already working for FRA, to independently review CAWG's findings concerning each of the 19 cases. The expert corroborated CAWG's independent alertness evaluations. Material reviewed by Dr. Hursh originated from Federal Railroad Administration investigations, and in some cases National Transportation Safety Board investigations. CAWG then compared his alertness assessment with that of its independent findings, the result being that CAWG's methodology was determined sound.

Recommendation: Alertness
CAWG makes several general observations suggesting avenues for improvements in railroad industry habits and procedures to reduce the incidence of impaired alertness. First, working between midnight and 8 am is an operational necessity that entails an operational risk. This risk needs to be further recognized and countered by the railroad industry. The circadian impairment in alertness that occurs at this time of day is a biological fact. No amount of training, conditioning, or motivation can eliminate the risk of lapses in attention that can occur at these hours. Procedural innovations should be devised to create redundancy and error checking to counter this natural phenomenon.

CAWG believes adequate sleep leading up to night work and napping immediately prior to a night shift are important countermeasures for minimizing the effects of the circadian reduction in alertness occurring between midnight and 8 am. Getting this sleep is a shared responsibility of employees and management. The employees must be trained and encouraged to:

- Understand the importance of adequate sleep and good sleep hygiene.

- Make personal decisions to incorporate evening naps into their daily routines.

- Plan activities so sleep is properly timed to minimize both chronic and acute sleep debt.

Management has a major role in enabling these behaviors. Unexpected or unplanned calls to work in the evening make it difficult for employees to take naps in anticipation of an evening call. It is unrealistic to expect employees to take naps in the evening when the family is at home unless there is a reasonable expectation they will be called to work. In short, evening calls for night work should be as predictable as possible. An unexpected call in the morning for a day shift is almost never a problem for alertness because it usually follows a night of sleep and coincides with the up-swing in normal circadian alertness. Unexpected calls in the evening are precisely the opposite; the person has already been awake for ten to twelve hours and will experience acute sleep debt. The work shift will coincide with the down-swing in circadian alertness. Operational procedures that increase the predictability of evening and night calls make it possible for employees to take necessary naps that minimize impairments to night-time alertness.

INTRA-CREW COMMUNICATION

Findings and Discussion: Intra-crew Communication

CAWG examined the interviews conducted and data reported for the crews, attempting to document each individual's performance of assigned duties during the time previous to the collision when track authority was exceeded and up to the actual impact, noting whether the crew member stayed aboard or jumped.

Recommendation: Intra-crew Communication

When there are two or more train and engine service employees in the cab of a locomotive, there should be an established process to ensure that every wayside signal, directive, instruction, and order is clearly and completely understood and properly executed by every crew member. Other activities must not interfere with the safe operation of the train. Particular attention to movement authority is needed when trains meet, one train overtakes another train, or when train operations occur in the vicinity of yards or industries where other train movements take place. There are ongoing crew resource management efforts.[5]

HIGH-RISK HOLIDAY PERIODS

Findings and Discussion: High-Risk Holiday Periods

[5] The FRA's Human Factors Research Program and the Office of Safety have jointly sponsored an extensive program of research and development on crew resource management (CRM) training in the railroad industry. The CRM program has four components: 1) a review of CRM training methods, the types of teams found in the railroad industry, and the matching of team types with the most appropriate CRM training methods; 2) the development of curricula appropriate for CRM training for crews in transportation crafts (locomotive engineers, conductors, dispatchers, switchmen, brakemen), engineering crafts (MOW, signal maintainers, electrical catenary crews), and mechanical crafts (machinists, electricians, pipe fitters, carmen); 3) the implementation and evaluation of a pilot training program at a Class I railroad; and 4) the development of a business case for CRM training in the railroad industry.

Reports on the components of the CRM program are under review and will be posted on the FRA website when approved for publication. In addition to these reports, training course materials for the transportation, engineering and mechanical crafts will also be available.

While main-track train collisions have occurred at any time of year, based on the 65 collisions reviewed by CAWG, there are two high-risk periods for main-track train collisions:

- One week period bracketing Independence Day (July 4th.).

- Three-week period bracketing Christmas (December 25th) and New Year's Day (January 1).

In the six-year period 1997 through 2002, there were 10 collisions during the four-week (per year) holiday period. This exposure over the six-year period equals 24 weeks (6 x 4). Ten collisions over 24 weeks is an incidence risk of 0.42 collisions per week (10 / 24 = 0.42). The remaining 55 collisions occurring over the complementary six-year, 288-week period (6 x [52 – 4]) corresponds to an incidence risk of 0.19 (55 / 288 = 0.19). The relative risk (RR) for the four-week holiday period is 2.21 (RR = 0.42 / 0.19). A statistical test applied to the differences in incidence risk indicated significance at the 95 percent level.

Reasons for the increased risk are not apparent from the review of the 65 main-track train collisions. If train traffic is reduced during the two holiday periods above, then the increase in risk during these four-weeks is more dramatic. Three other holiday periods – Memorial Day, Labor Day, and Thanksgiving – were not found to be at higher risk.

Recommendation: High-Risk Holiday Periods
The potential exists for the industry to better understand the reasons for the high-risk periods for main-track train collisions. Identifying the reasons could bring opportunities for prevention. Studies directed towards understanding should be undertaken. These studies need not be specific to main-track train collisions. Studies could include all human-factor related undesirable outcomes including collisions and employee casualties. These findings may identify and reduce risk during holiday periods.

The industry should alert employees to the increased risk during these periods.

END OF TRAIN DEVICES (EOT),

49 CFR Part 232, Subpart E

Findings and Discussion: End of Train Devices (EOT)
CAWG could find little evidence of testing and data collection on the effects of EOT activation in emergency train brake applications. How much stopping distance was actually saved by simultaneous application of the EOT? Obviously, train speed effects distance in feet. CAWG wonders whether it is proportional for speed, or if the percent benefit in stopping distance saved is greater for higher train speeds. CAWG conducted a literary search for industry data on any available research and testing on this issue. CAWG was unable to establish any definitive research or studies.

CAWG canvassed the railroad industry with little success. A few railroads responded with experience, mostly anecdotal that with the existing train brake system, "The automated feature for the 2-way valve on the rear of the train has minimal affect on stopping distance. If the emergency application actually occurred simultaneously at both ends of the train (as simulations we performed were done to evaluate this issue) stopping distance is improved approximately 10 percent."

Recommendation: End of Train Devices (EOT)
Training programs should be created, conducted, and documented on a continuing regular basis to ensure engineers are able to instinctively activate the EOT when the train brakes are put into emergency. CAWG suspects that junior engineers are probably made aware and qualified during their training. More senior engineers are of greater concern to CAWG, since instruction and review of the practice must overcome years of experience without a two way EOT to activate. This shortcoming potential for more senior engineers may manifest itself under time-critical performance of operational duties. EOT training should be included in locomotive engineer evaluations and, when possible, in rule efficiency checks. Training should also include train crew awareness of whether or not the locomotive in the lead that they are operating will activate the EOT automatically; or whether it requires manual activation. This question becomes critical as more of the new locomotives come on line.

All locomotives ordered on or after August 1, 2001, or placed in service for the first time on or after August 1, 2003, shall be designed to automatically activate the two-way, end-of-train device to effectuate an emergency brake application whenever it becomes necessary for the locomotive engineer to place the train's air brakes in emergency. [from 49CFR Part 232.405(f)][6]

Data driven simulation and actual research should be conducted and published for the railroad industry, and train crews in particular, to clearly understand the impact and importance of this issue; and the effects of EOT activation when the train brake is placed in emergency from the lead locomotive.

CRASHWORTHINESS

Findings and Discussion: Crashworthiness
Locomotive crashworthiness is important to the survivability of locomotive crews given that a collision has occurred. The intent of CAWG was not to determine the crashworthiness of various locomotives, or the advisability of crews staying in, or jumping from, the locomotive given collision certainty. However, from the review and analysis of the 65 collision cases, information was generated of likely interest to those engaged in locomotive crashworthiness. CAWG wants to make those interests aware of this information now contained in the CAWG Database.

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[6] During the 1990s, prior to this requirement, several railroads had initiated this practice.

Some analysis, however, was performed. Logistic regression was used to analyze the risk of injury and fatality in collisions from the decision to jump from, or stay in, the locomotive. This multivariate technique controls for confounding variables while testing the effect of interest – whether the employee's decisions to exit or stay, given collision certainty, changed the risk of injury or fatality. Factors controlled for affecting the risk were: train speed, collision type, whether the locomotive was built to S-580 standards. The current S-580 standards are contained in the Appendix. CAWG again stresses that crashworthiness was not a study purpose, and its review and analytical methods did not include a study design to best capture crashworthiness information.

The analysis produced the following results:

- The probability of injury was greatly affected by the decision to exit or stay with the locomotive. Eighty-seven percent of employees who exited the locomotive were injured compared to 51 percent who stayed with the locomotive.

- There was no significant indication in the data that the decision to exit or stay with the locomotive changed the likelihood of fatality. The probability of a fatality was greatly affected by train speed.

Recommendation: Crashworthiness

CAWG suggests that future groups studying crashworthiness may find our efforts of some use as a baseline point as enhanced safety equipment and changes brought on by the continued development of S-580 standards. (Refer to Federal Railroad Administration's (FRA's) Website.[7])

OPERATING METHODS

Findings and Discussion: Operating Methods

CAWG compared collisions occurring in Traffic Control System (TCS) territory to those occurring in train order territory[8] (e.g. track warrant territory). The purpose of the comparison was to determine whether the number of collisions per million train miles is different in one type of territory versus another. The comparison was difficult to conduct because the current accident reporting form does not have a consistent process of reporting methods of operations. (See the finding on accident reporting below.)

After considerable review and discussion, CAWG was able to determine the method of operation for all collisions. Table E-1 shows 45 CAWG collisions in TCS territory and 12

[7] On Federal Railroad Administration's (FRA's) Website: Click on 'Research and Development', then 'Research Reports'. Studies include DOT/FRA/ORD-02/03, DOT/FRA/ORD-01/23, DOT/FRA/ORD-95/08, and DOT/FRA/ORD-95/08I through 95/08V.

[8] *Train order territory* is defined herein as territory within which written authority is required for train movements.

collisions for train order territory.[9] The remaining 8 collisions occurred in other situations.

Table E-1. Collisions by Territory Type

Territories from Volpe Center Study	Train Miles From Volpe Center Study	CAWG Collisions	Collisions per million Train Miles
Auto	44,220,891	6	
CTC	300,580,358	39	
Total for TCS	**344,801,249**	**45**	0.131
ABS	80,773,696	8	
Dark	58,600,600	4	
Total for Train Orders	**139,374,296**	**12**	0.086
Interlockings, Yard Limits, Form Bs	-----	8	-----

Using estimated train miles by territory from a Volpe Center study,[10] CAWG was able to form an estimated collisions per million train miles for each type of territory. The collision rate for train order territory, 0.086, is not higher than the collision rate, 0.131, for TCS territory. CAWG expected the number of collisions per million train miles for train order territory[11] to be significantly higher than TCS territory, so this is a surprising result. Most expected the additional computer assisted data and information developed with TCS to reduce exposure unique to train order territory, where additional manipulation and oversight by crew members is required; and thus, train order territory would be expected to be subject to additional human failure.

Two study limitations may account for this unexpected result:

[9] As mentioned, *Train order territory* is defined herein as territory within which written authority is required for train movements.
[10] *Base Case Risk Assessment: Data Analysis & Tests*. Study done by the John Volpe National Transportation Systems Center for the Office of Safety, Federal Railroad Administration. RSAC/PTC Working Group Risk 2 Team. Updated April 19, 2003.
[11] As mentioned, *Train order territory* is herein defined as territory within which written authority is required for train movements.

- CAWG collisions do not represent all collisions.[12] For example, CAWG selected only those collisions having an FRA HQ investigation number; and from those, collisions where trains exceeded authority. Situations where crews improperly gave up authority, such as misaligning a manual switch, are not covered by CAWG.

- Collisions for 2003 and 2004 are not covered in this report. Adding CAWG collisions for these years could change the estimated collision rates in a significant way.

A PCF profile of the two types of territories sheds light on the different collision rates associated with the two territories (Table E-1).

In train order territory, Table E-1 identifies problems with intra-crew communication in 4 of the 12 cases; this is a significantly higher ratio than the corresponding ratio for TCS of 5 out of 45 cases.

Table E-1 also shows all collisions where at least one employee was asleep occurred in TCS territory. Table E-1 indicates alertness is more of a risk factor in this type of territory. The 12 cases in train order territory did not identify any employee being asleep. This risk factor may partially explain why TCS territory does not exhibit a lower CAWG collision rate than train order territory.

Recommendation: Operating Methods
CAWG suggests a potential finding of differences in crew alertness between TCS and train order territory, but does not make a recommendation.

COLLISION INVESTIGATION AND REPORTING

Findings and Discussion: Collision Investigating and Reporting
<u>Collect Human Factor Data</u>
After reviewing the first 14 collision cases, CAWG decided to rate the quality of the Federal Railroad Administration's investigation. Seven cases (14 percent) were rated 'very good'; 26 (50 percent), 'good'; 17 (34 percent), 'fair'; and 1 (2.0 percent), 'marginal.'

Those cases rated as either very good or good contained detailed information concerning each employee's work history, experience, training, the level of management oversight, and work/rest histories going back at least 10 days. Those cases rated fair or marginal by CAWG did not contain many of the items listed for various reasons. These findings led CAWG to discuss how FRA conducts a collision investigation, what is required, and why FRA does not, as a rule, investigate and document an employee fatality as the result of a

[12] The Volpe Center study formed rates by territory from approximately 800 collisions. These collisions were selected based on being preventable by a Level 3 PTC system and having total damages exceeding the FRA's monetary reporting threshold.

human factors collision with the same level of thoroughness as an employee on duty fatality (FE).

Where human factor issues were not fully developed in cases, CAWG felt that “root cause analysis,” with accurate conclusions and beneficial recommendations, could not always be clearly established. However, since the end of the CAWG study period (2002) additional training has been provided for FRA Inspector forces; and regional management has been re-trained on Accident/Incident Investigation Review. This effort, along with personnel changes at FRA’s Accident Analysis Branch have led, in many cases, to a more comprehensive and standardized final report, particularly over the last four years. Additionally, the FRA and some railroads are in the process of developing new human factor tools that have the potential to be useful when applied to accident/incident investigation.

Recommendation: Collision Investigating and Reporting
Collect Human Factor Data
FRA should identify and document all relevant human factor data. This data includes crew members’ experience on the territory where the collision occurred, their age, experience in craft, and railroad seniority of each of the crew members in the collision (striking and struck crews). A work/rest history that clearly indicates off and on-duty times for both train crews and accompanying paperwork on how off duty time was spent, if possible, should go back a minimum of 10 days. CAWG recommends a review of management oversight for all of the violating train crew-members. The oversight should include training results and a review of the number of efficiency tests performed on each crew member during the last 6 months, the number directly related to the incident and the number of tests passed and failed.

Findings and Discussion: Collision Investigating and Reporting
Update CAWG Database
The experience gained by the Switching Operations Fatality Analysis (SOFA) Working Group (SWG) development and analysis of a data matrix was valuable to the CAWG’s work and endeavors. The SWG entered detailed information on the 76 switching fatalities upon which its October 1999 [13] study was based, into a Microsoft® Excel spreadsheet. By continuing to review and add switching fatalities to its ‘SOFA Matrix’, the SWG created retrievable, electronic records of 124 fatalities. Integrating the information on the additional 48 switching fatalities with that of the original 76 fatalities allowed the SWG to further identify additional operational exposures to fatalities, in the form of Special Switching Hazards, to employees engaged in switching operations. CAWG would benefit from additional case analysis.

Recommendation: Collision Investigating and Reporting
Update CAWG Database
The CAWG Database allows for quick retrieval and querying of information on the 65 main-track train collisions occurring from 1997 through 2002. CAWG recommends that its Database be updated for 2003 and 2004 collisions meeting the established criteria.

[13] *Findings and Recommendations of the SOFA Working Group*. October 1999.

Additional years of information will allow for up-to-date querying to determine present risk factors and commonalities with past collision events.

Findings and Discussion: Collision Investigating and Reporting
<u>Reporting Signal Information</u>
CAWG notes that some collisions occurred in territory where the transiting train encountered the sequence GREEN, YELLOW, RED. CAWG considered the benefit of a fourth signal: FLASHING YELLOW, or two consecutive YELLOWs, giving a greater advanced warning time to an absolute stop signal. Changes in the configuration of existing signals may have provided beneficial results to safe operations in some of the collisions reviewed. However, the data files, which CAWG had available and reviewed, did not contain sufficient data and information on signal systems to establish and/or evaluate. Therefore, CAWG could not make a determination about the collision-prevention value, if any, of a four- signal sequence as opposed to a three.

Many cases contain information about crew members' perceptions of signal aspects prior to a collision. This information was derived from testimonies taken from those affected during post-collision interviews. Given that Distant Signals (the signal preceding a Home Signal) are not routinely equipped with recording devices and therefore cannot create a record of what aspect the Distant Signal was displaying, the investigation regarding specific signal aspects preceding the collision is based upon the testimonies of carrier officials, affected train crew members, signal tests that have been performed on the signals in question and information gleaned from data and event recorders at the Control Point or Interlocking where the collision took place. When these tests and signal reports contradict the crew member's testimony, it is assumed that the crew member did not correctly remember the signal indication. It appears that at times, detailed information on signal issues is not identified, collected, documented, and reported. Until this information is systematically collected, a system wide database cannot be developed capable of being queried regarding the number of collisions occurring in three signal-sequence territory, as opposed to the number occurring in territory equipped with a four sequence-system. Without this level of relevant information and data, CAWG believes that future working groups will be unable to establish specific conclusions and effect meaningful safety improvements.

Recommendation: Collision Investigating and Reporting
<u>Reporting Signal Information</u>
In an effort to build a reliable data base, CAWG recommends that reporting of post incident testing involving signal systems include information on the type of signal system, model number of signal apparatus, and aspects from each signal. Aspect information should be gathered from an adequate number of signals to clearly identify all those relevant to the incident. Signal apparatus information should include the type and number of heads located on each signal mast.

Finding and Discussion: Collision Investigating and Reporting

<u>Reporting Method of Operations</u>

CAWG found inconsistencies regarding the entries made to field number 30 (Methods of Operation) on form *FRA F6180.39* used by FRA Investigators to record objective data about the accident they are investigating. Often, commingling signal authority with safety overlays. For instance, a train operating in Traffic Control System (TCS) territory will also be governed by automatic block signals; therefore, it is redundant to use both the "e" and the "g" codes. Further, the practical difference between "I"-Timetable/train order, "j"-Track warrant, and "k"-Direct traffic control is negligible when annotating a block used to indicate a "method of operation" and could certainly be spelled out later on in the report if necessary to clarify why the accident occurred as the result of one of these methods of operation and may not have happened using another.

CAWG invested considerable effort to convert the reported codes into a framework that was useful for analysis.

Recommendation: Collision Investigating and Reporting

<u>Reporting Method of Operations</u>

FRA should review block 30 on the most recent form *FRA F6180.39* (Revised July 2003) and determine which methods of operation belong in the block, which methods of operation should be combined, and which methods should be removed. CAWG believes FRA would create a more standardized and efficient way of sorting on the method of operation in effect at the time of the incident.

OVERVIEW

In June 2002, Allan Rutter, then Administrator for the Federal Railroad Administration, proposed creation of the Collision Analysis Working Group (CAWG) for the purpose of reviewing main-track train collisions with the intent of making preventive findings and recommendations should the facts warrant.

CAWG held its first meeting on July 17-18, 2002; and its final meeting on February 9-11, 2005. During the intervening period, CAWG met twenty-six times to review and analyze 65 main-track train collisions and to develop findings and recommendations based on the commonality of facts. Often these collisions resulted in personal injuries or fatalities. This study discusses the review and analysis of the 65 main-track train collisions, the principles upon which this process was based, and the findings and recommendations thought helpful in preventing similar occurrences.

Because of continuing fatalities to employees engaged in switching operations, CAWG members, all who serve as Switching Operations Fatality Analysis Group representatives, suspended their CAWG work and researched, analyzed, and wrote the report *Findings and Recommendations of the SOFA Working Group: August 2004 Update*, as well as releasing other switching operations safety information.

1. INTRODUCTION

1.1 CAWG Scope

CAWG reviewed and analyzed 65 main-track train collisions occurring from January 1997 through December 2002. These collisions, of both freight and passenger trains, involved human-factor issues. In this study, the review and analysis process is described and findings and recommendations, based on commonalities, are given to prevent future main-track train collisions.

1.2 Background of CAWG

Federal Railroad Administrator Allan Rutter proposed on June 4, 2002, that a Collision Analysis Working Group (CAWG) be established to review and analyze main-track train collisions and make safety findings and recommendations based on commonalities – should the facts warrant. This proposal provided the railroad industry with an unique opportunity to re-examine relevant safety policies and practices. Administrator Rutter encouraged participation from representatives of the railroad industry.

Holding its first meeting on July 17-18, 2002, in Alexandria, VA, CAWG initially agreed to review 49 collisions where human factors contributed to trains exceeding their authority by (1) passing a stop signal; (2) failing to comply with a signal requiring restricted speed; (3) entering territory without a train order, track warrant, or direct traffic control authority. These 49 main-track train collisions occurred during a five-year period from January 1, 1997 through December 31, 2001.

Subsequently, at its August 2003 meeting, CAWG expanded the number of collisions it would review, by adding the 16 qualifying main-track train collisions occurring in 2002. The decision was based on two factors. First, to increase the number of collisions being reviewed so any commonalities would become more apparent; and second, to make the findings and recommendations contained in this study as current as possible. CAWG believes these 65 collision cases are enough to find meaningful commonality while not unduly delaying collision-avoiding information from reaching the railroad industry.

The first collision case reviewed by CAWG occurred on July 2, 1997 at Kenefick, KS, No. 1. (*CAWG No.s*, indicating the review order, are used to uniquely reference each case.) The most recent collision reviewed occurred on November 5, 2002 at Valley Pass, NV, No. 65. Cases were not necessarily reviewed in chronological sequence of occurrence. A narrative summary of each collision case is included in the next section of this study, referenced by its CAWG No.

Each of the six years, 1997 through 2002, contains all the main-track train collision cases that met CAWG's selection criteria described below. However, all of the 2003 investigations were not completed when the review of these 65 cases was finished. CAWG felt extending the publication date of this study would unduly delay this collision-avoiding information from reaching the railroad industry. CAWG stresses that many collisions were associated with human casualty both to railroad employees and passengers, a fact re-emphasizing the importance of timely dissemination of prevention information.

Because of continuing fatalities to employees engaged in switching operations, CAWG members, all who serve as Switching Operations Fatality Analysis Group representatives, wrote and issued the report *Findings and Recommendations of the SOFA Working Group: August 2004 Update*, as well as releasing other switching operations safety information.

1.3 Objectives

CAWG's main collision review and analysis provides the railroad industry with an opportunity to re-examine its safety policies and practices based on commonality of facts found among the 65 collisions.[14] Taking note of the findings and recommendations will ensure reasonable precautions are taken to prevent future collisions.

1.4 Methods

Selection criteria

CAWG's review and analytical methods consisted of case selection based on a series of main-track train collisions occurring, 1997 through 2002, involving human factor issues:

- Collisions must have been assigned a FRA HQ investigation number. All Amtrak collisions are assigned a FRA HQ investigation number. Note, not all freight collisions receive a FRA HQ investigation number. Thus, the 65 selected main-track train collisions consist of all Amtrak collisions plus the major freight collisions assigned a FRA HQ investigation number, occurring during the study period.

- Each collision must occur during main-track train operations. Thus, yard collisions are eliminated. Yard collisions may result from different factors than main-track train collisions.

- Except for passenger trains,[15] each collision must involve a train having at least two crew members on the locomotive consist. Collisions occurring during switching operations and miscellaneous one-person train crews are eliminated.

- Each collision must involve a train exceeding its authority by (1) passing a stop signal; (2) failing to comply with restricted speed; and/or (3) entering territory

[14] Contemporary accident investigation goes beyond the simplistic approach of blaming the accident on the operator(s) and moves toward a comprehensive analysis where human error is seen as a symptom of deeper trouble. In this procedure, an accident event is an opportunity to recognize that human error is the starting point for an investigation. The investigation ought to reveal how human error is systematically connected to the tools, tasks, operations, and organizational environment.

[15] Qualifying passenger train collisions are included even though many passenger trains are operated with a lone engineer. The criteria concerning "at least two crew members on the locomotive consist," to eliminate switching operations, does not apply to these types of movements.

without train order, track warrant, or direct traffic control authority. Thus collisions resulting from vandalism and adjacent track events are eliminated.

Review process

After selecting 65 cases meeting its criteria, CAWG reviewed and discussed each case. CAWG members were assigned cases as 'homework' to become familiar with, and present a case description at the next CAWG meeting. Case information was derived from Federal Railroad Administration investigations and, in some instances, National Transportation Safety Board investigations.

During the presentation, quantitative and narrative case information was entered into a Microsoft® Access database that came to be known as the 'CAWG Database.' Descriptive information entered included:

- Collision location, time, weather;
- Operating conditions noting any special restrictions;
- Consist characteristics noting any defects; and
- Crew description and location during the time previous to the collision when authority was exceeded and up to the actual impact, noting whether crew stayed onboard or jumped.

Appendix H provides a full listing of data elements used. After entering the detailed description information for each of the 65 collision cases, CAWG began its discussion of commonalities and causality, the latter often expressed as Possible Contributing Factors (PCFs). CAWG's approach to causality, based on PCFs, is discussed below along with coding conventions to capture, in retrievable form, key aspects of causality.

Analysis – searching for commonalities

As mentioned, once review of the 65 cases was completed, and a quality check made of the information contained in the CAWG Database, the process of discovering commonalities began. The CAWG Database, with its Boolean[16] search and retrievable characteristics, allowed quick calculation and display of commonalities among the 65 collision cases without interrupting CAWG's flow of discussion and analysis. CAWG, based on the consensus of its members, developed findings and recommendations from the commonality of information contained in the CAWG Database. CAWG findings and recommendations in general involve human factor issues: alertness including work/rest and shared crew responsibility issues, crew experience and optimal makeup based on that experience, and operation procedures and methods.

[16] Boolean searches allow the joining of simple searches or queries by the words *and*, *or* and *not*. For instance, the CAWG Database can retrieve information on collisions occurring between 4 and 6 am, *and* involving crews with less than five-years experience *or* more than thirty-years experience, but *not* the result of extreme environmental conditions.

1.5 CAWG's Approach to Causality

CAWG developed an approach to collision 'causality' based on consideration of an often complex combination of rail-system operating characteristics, conditions, and events.[17] CAWG in determining causality does not attempt to rank these factors, usually expressed as Possible Contributing Factors (PCFs).

CAWG used the FRA's "Train Accident Cause Codes"[18] and its own defined codes as the basis for PCFs. Each collision was assigned as many PCFs as CAWG believed applied; however, the number of PCFs applied to a collision case did not go beyond the number necessary to capture the essence of the identified factors. CAWG avoided redundancies. As mentioned above, CAWG does not attempt to rank PCFs. Causal information not appropriately captured by a PCF was described in narrative form.

1.6 Study Limitations

CAWG recognizes its review of 65 main-track train collisions contain limitations to the type and depth to which safety-related issues were explored. Such limitations apply to crashworthiness, alertness, crew resource management, and other subject areas affecting safe operations. Safety studies, in general, make advances to existing knowledge and with additional information and thought undergo modification. As such, this study offers opportunity for subsequent safety groups, and subject-matter experts, to improve operating practices by exploring in depth the issues raised in, and related to, this study.

1.7 Results

Findings and recommendations made in this study apply to main-track train collisions and not yard, highway-rail, or switching operation collisions. Rarely are main-track train collisions the result of a single factor or cause. Review of the 65 collisions clearly establishes that most collision events are a combination of unrelated factors and deviations occurring at the same time, at the same location, and on the same train. Sometimes, these factors and deviations do not rise to the level of identifiable violations of operating rules, federal regulations, and/or industry standards; the greater the number of factors and deviations present, the more likely a collision.

1.8 Importance of Collision Prevention

Eliminating main-track train collisions will prevent enormous harm. CAWG wants to emphasize that although the 65 collision cases are 'accidents' in the sense physical damage exceeded the Federal Railroad Administration defining monetary threshold, main-track train collisions often are associated with human casualties. The 65 main-track train collisions resulted in 16 fatalities and 531 injuries. There were 14 employee fatalities and 128 employee injuries; 2 passenger fatalities and 403 passenger injuries.

[17] Contemporary accident investigation goes beyond the simplistic approach of blaming the accident on the operator(s) and moves toward a comprehensive analysis where human error is seen as a symptom of deeper trouble. In this procedure an accident event is an opportunity to recognize that human error is the starting point for an investigation. The investigation ought to reveal how human error is systematically connected to the tools, tasks, operations, and organizational environment.

[18] Contained in Appendix C, pages 1-11, of the *FRA Guide for Preparing Accident/Incident Report*. Federal Railroad Administration. 1997.

(One passenger collision in Placentia, CA, No. 53, accounted for all the passenger fatalities and 163 passenger injuries.) There was $83,108,072 in track, signal, lading, and equipment damage. The most damage in one collision (Pacific, MO, No. 49) was $7,855,920, average damage being $1,278,586. There were 42 hazardous material cars derailed, and four hazmat releases. Numerous other costs – direct, indirect, and opportunity – are associated with collisions, some calculable, some not.

2. SIXTY-FIVE MAIN-TRACK TRAIN COLLISIONS

2.1 Overview

This study is based on the Collision Analysis Working Group (CAWG) review of 65 collisions occurring from January 1997 through December 2002. The selection criteria for those collision cases are described below. Information from the review and analysis was entered into the CAWG Database, allowing for quick retrieval and querying of information as an aid in establishing commonalities. CAWG's intent is to ensure that subsequent main-track train collisions will be added to the CAWG Database, thereby allowing for up-to-date analysis. A narrative summary of each of the 65 cases is presented at the end of this section.

2.2 Selection Criteria

CAWG's selection criteria for the 65 main-track train collisions was presented in the Introduction and is repeated here for reference:

- Collisions must have been assigned a FRA HQ investigation number. All Amtrak collisions are assigned a FRA HQ investigation number. Note, not all freight collisions receive a FRA HQ investigation number. Thus, the 65 selected main-track train collisions consist of all Amtrak collisions plus the major freight collisions assigned a FRA HQ investigation number, occurring during the study period.

- Each collision must occur during main-track train operations. Thus, yard collisions are eliminated. Yard collisions may result from different factors than main-track train collisions.

- Except for passenger trains,[19] each collision must involve a train having at least two crew members on the locomotive consist. Collisions occurring during switching operations and miscellaneous one-person train crews are eliminated.

- Each collision must involve a train exceeding its authority by (1) passing a stop signal; (2) failing to comply with restricted speed; and/or (3) entering territory without train order, track warrant, or direct traffic control authority. Thus collisions resulting from vandalism and adjacent track events are eliminated.

2.3 Collision Case Summaries

The 65 main-track train collision cases are listed in Table 2-1 in chronological order. Each case was assigned a CAWG reference number. These numbers were assigned in the

[19] Qualifying passenger train collisions are included even though many passenger trains are operated with a lone engineer. The criteria concerning "at least two crew members on the locomotive consist," to eliminate switching operations, does not apply to these types of movements.

order the cases were reviewed, which is slightly different from the chronological occurrence of the collisions.

Table 2-1. Sixty-Five Main-Track Train Collisions, 1997 through 2002

#	Location	Date	CAWG No.	#	Location	Date	CAWG No.
1	Lagro, IN	05/31/97	6	**34**	Kenner, LA	12/21/00	29
2	St. Albans, WV	06/07/97	7	**35**	Malden, TX	12/21/00	30
3	Kenefick, KS	07/02/97	1	**36**	Woodburn, IA	12/27/00	31
4	Hummelstown, PA	09/29/97	5	**37**	Racine, MO	01/14/01	38
5	North Bay, CA	10/16/97	8	**38**	Syracuse, NY	02/05/01	3
6	Borderland, WV	10/23/97	9	**39**	Carlisle, OH	02/17/01	39
7	Houston, TX	10/25/97	10	**40**	Richmondville, NY	04/09/01	40
8	Navasota, TX	10/29/97	12	**41**	Glenwood, IA	08/18/01	41
9	Welka, AL	11/02/97	13	**42**	Ransom, IL	08/20/01	42
10	Alvord, TX	11/03/97	4	**43**	Jacksonville, TX	09/07/01	43
11	W. Memphis, AR	12/14/97	11	**44**	Hallsville, TX	09/11/01	44
12	Herington, KS	03/23/98	14	**45**	Wendover, UT	09/13/01	45
13	Butler, IN	03/23/98	15	**46**	Andersonville, MI	11/15/01	46
14	Creston, IA	03/28/98	16	**47**	Mayfield, OH	11/28/01	47
15	Orin, WY	09/12/98	17	**48**	Pacific, MO	12/13/01	49
16	Stryker, OH	01/17/99	18	**49**	Kenner, LA	12/15/01	50
17	Momence, IL	03/23/99	19	**50**	Bradford, IL	01/01/02	51
18	Mt. Pleasant, TX	04/15/99	20	**51**	La Porte, IN	02/03/02	52
19	Jacksonville, FL	07/01/99	2	**52**	Placentia, CA	04/23/02	53
20	Palm Springs, CA	07/05/99	21	**53**	Douglas, WY	05/11/02	54
21	Perkins, WY	07/22/99	32	**54**	Clarendon, TX	05/28/02	55
22	Clinton, IA	08/11/99	33	**55**	Aurora, IL	06/12/02	56
23	Wickes, AR	09/13/99	34	**56**	Leesburg, TX	06/16/02	57
24	Cumberland, MD	09/20/99	35	**57**	Baltimore, MD	06/17/02	58
25	Waldeck, KS	11/13/99	36	**58**	North Platte, NE	06/19/02	59
26	Fullerton, CA	11/18/99	37	**59**	Jamaica, NY	06/22/02	60
27	Tyrone, OK	06/01/00	22	**60**	San Bernardino, CA	06/30/02	61
28	Cincinnati, OH	09/04/00	23	**61**	Vader, WA	09/15/02	62
29	Kingman, AZ	09/16/00	24	**62**	Reddick, IL	10/10/02	63
30	Bellemont, AZ	10/31/00	25	**63**	Des Plaines, IL	10/21/02	64
31	Yarmony, CO	11/04/00	26	**64**	Valley Pass, NV	11/05/02	65
32	Laredo, MO	11/20/00	27	**65**	Swenney, TX	12/06/02	48
33	Murray, NE	12/18/00	28				

Narrative summaries, written by CAWG, for each of the 65 collision cases are presented below. Summaries of 2003 and 2004 collision cases, qualifying for CAWG review, are also given. As mentioned, the 2003 cases for which some investigations had been completed, and the 2004 cases, were not reviewed to allow for timely release of the study's findings and recommendations.

CAWG No. 1 Kenefick, KS **02-Jul-97**

At about 0215, in CTC territory, a westbound freight train moving at 1-2 mph struck the side of a 70 mph eastbound freight train six cars behind the engine at the west end of the controlled siding at Kenefick, near Delia, KS. A serious diesel fire engulfed hazmat cars that were derailed. 1500 people were evacuated. The engineer on the westbound train died in the collision.

CAWG No. 2 Jacksonville, FL **01-Jul-99**

At 0309, a southbound passenger train attempting to pass through a three-mile long temporary DTC block, where a signal suspension was in effect, ended up striking the side of a northbound passenger train which was taking the siding at 13 mph through a hand-throw switch. The lone engineer on the southbound train attempted to communicate with switch tenders inside the signal suspension territory via radio to comply with the requirement in a General Bulletin while maintaining the 59 mph track speed and failed to stop at the first operational controlled signal at the south end of the suspension where the northbound train was diverging.

CAWG No. 3 Syracuse, NY **05-Feb-01**

At 1140, a passenger train that had just made a crew change, accelerated to 59 mph before passing a signal that required restricted speed. The passenger train collided with the rear end of a freight train that was standing on a right hand curve. The lone engineer had distracted himself while running by turning and reaching down into his grip. One of two locomotives and four of the five passenger cars were derailed.

CAWG No. 4 Alvord, TX **03-Nov-97**

At about 1210, a relatively inexperienced engineer and a conductor with less than one year of experience operated a loaded coal train in TWC/ABS territory. Due to an obstructed brake pipe, the air brakes on the striking train failed to stop the train at the end of its authority. The rear-end collision with an empty coal train occurred at a speed of approximately 15 mph. Both crew members jumped prior to impact and received only minor injuries.

CAWG No. 5 Hummelstown, PA **29-Sep-97**

At 1745, a 13,000-ton freight train collided with a standing light engine. Before the collision, the engineer on the striking train put his train in emergency and followed the conductor out the rear door of the locomotive. The conductor was killed in the ensuing collision. The lens of the previous signal was later discovered to be discolored by water in the signal head and reenactments of the incident showed that the signal was displaying a "phantom" aspect.

CAWG No. 6 Lagro, IN **31-May-97**

At about 740, a westbound train with a crew which had been on duty for over 11 hours passed a stop signal at the west end of a controlled siding and struck the side of an eastbound train at a speed of about 9 mph. The conductor sustained minor injuries.

CAWG No. 7 St. Albans, WV 07-Jun-97

At 2205, an 8100-ton eastbound mixed freight train being operated by an experienced engineer and a qualified conductor (with a student conductor on board), struck the rear end of an eastbound coal train standing just beyond an intermediate signal. An Approach Signal was displayed 1.4 miles from this Restricted Proceed grade signal. The speed at the time the striking train went into emergency was 39 mph. Speed at impact was approximately 30 mph. The rear car of the standing train climbed the nose of the striking locomotive and the engineer was killed. Hazmat was released from a punctured tank car and a fire ensued.

CAWG No. 8 North Bay, CA 16-Oct-97

At about 1500 on October 16, 1997, after waiting five minutes, a local switcher with two locomotives and 15 cars entered the main on TWC authority in ABS territory at a hand-throw switch. The crew exceeded restricted speed and was unable to stop short of a standing cut of cars set out on the main without authority at the next station east of them. Speed at impact was 22 mph. Two platforms of a five-car articulated set were derailed.

CAWG No. 9 Borderland, WV 23-Oct-97

At 1305 hours, a westbound train being operated by a student engineer (under the guidance of a qualified engineer) failed to stop at a crossover in Traffic Control territory and ran out into the path of a 12,000-ton eastbound coal train approaching the crossovers on a diverging-clear signal. The westbound train was stopped when the collision occurred. All crew members jumped and several received serious injuries.

CAWG No. 10 Houston, TX 25-Oct-97

At 1450 hours, a westbound train collided head-on with a standing eastbound train in CTC territory. The westbound train crew passed an Approach Signal and was attempting to slow the train but an obstruction in the brake pipe of the fourth locomotive on the striking train prevented the proper operation of the air brakes.

CAWG No. 11 West Memphis, AR 14-Dec-97

At 0455 hours, a westbound freight train struck the side of a southbound freight train at an automatic interlocking in CTC territory (CTC for both railroads). The westbound, very experienced engineer had made several small brake pipe reductions while in idle, but failed to put the train into emergency soon enough to stop short of the absolute stop signal. He did induce an emergency application with the EOT device just before impact at 13 mph.

CAWG No. 12 Navasota, TX 29-Oct-97

At 0420 hours, a southbound freight train collided with the rear end of a southbound freight train that had stopped in CTC territory to do work. The striking train hit the standing train at a speed of 25 mph derailing the rear car of the standing train, the two striking locomotives, and ten cars of the striking train. No one was seriously hurt on either train.

CAWG No. 13 Welka, AL 02-Nov-97

At 1013 hours, an engineer operating a two locomotive light consist from the trailing end collided with the rear end of a train which was standing on a curve. The striking train had come out of a passing track after having been run around. The crew of the striking train had not changed ends when reversing direction after a switching move and poor communication contributed to this collision.

CAWG No. 14 Herington, KS 23-Mar-98
At 1055 hours, a westbound manifest freight train struck the rear end of a westbound intermodal train. A crimped air hose on the seventh car was found to have restricted airflow when the engineer attempted to slow down for the yellow and flashing red signals. The restricted brake pipe interfered with the train's braking power; and the rear end device was not activated from the head end.

CAWG No. 15 Butler, IN 25-Mar-98
At 0448 hours, a southbound freight train struck the side of an eastbound freight train where the two railroads intersected. The speed at impact was 30 mph. A student engineer was running from the controlling locomotive that had its long nose forward. The conductor on the striking train was killed after jumping from the rear catwalk just before the collision.

CAWG No. 16 Creston, IA 28-Mar-98
At 1035 hours, an empty westbound coal train struck the rear of a preceding standing empty westbound coal train at a speed of 30 mph while operating through yard limits on the main. The engineer placed the train into emergency approximately 20 seconds prior to impact, at a speed of 50 mph, but did not activate the EOT from the head end.

CAWG No. 17 Orin, WY 12-Sep-98
At 2035 hours, an eastbound loaded coal train (16,000 tons) collided with the rear end of a standing loaded coal train at a speed of 35 mph. Inexperience and territorial unfamiliarity induced the engineer of the striking train to operate without regard for the for the grade, the signals, and his ability to stop the train in accordance with signal indications. The conductor did not sufficiently monitor the engineer's performance.

CAWG No. 18 Stryker, OH 17-Jan-99
At 0158 hours, while operating in dense fog, a westbound freight train moving at 56 mph struck the rear end of a freight train moving at a speed of less than 10 mph. Event recorder data showed no braking activity prior to impact. The engineer and conductor on the striking train were killed.

CAWG No. 19 Momence, IL 23-Mar-99
At 0703 hours, an eastbound freight train struck a southbound freight train from another railroad at a railroad crossing at grade at a speed of 2 mph. The engineer had been qualified for approximately two years. The conductor was a 32-year veteran working his assigned pool.

CAWG No. 20 Mt. Pleasant, TX 15-Apr-99

At 1230 hours, a crew with very little time left to work failed to stop their freight train short of the rear end of a standing train near the place where they were supposed to get their 12-hour relief. After the engineer put the train into emergency, the conductor, the engineer, and the student engineer on the striking train jumped prior to impact and sustained minor injuries.

CAWG No. 21 Palm Springs, CA 05-Jul-99
At 0140 hours, westbound intermodal train ran by a stop signal at the west end of a controlled siding and into the path of an eastbound manifest freight train. The westbound came to a stop before the eastbound collided with the violating train. All four crew members were able to jump prior to impact. The engineer on the eastbound train received severe injuries during his fall.

CAWG No. 22 Tyrone, TX 01-Jun-00
At 1805 hours, an eastbound road switcher left a siding in DTC single-track, ABS territory ahead of a following intermodal train. The following train crew was attempting to get block authority ahead as they were approaching the west end of the siding. The struck train crew did not wait 5 minutes after lining the east switch and it was designated as the violating train.

CAWG No. 23 Cincinnati, OH 04-Sep-00
At 0815 hours, a two-person freight-train crew collided on main number two of three main within traffic control territory, with the rear of a stopped freight train. The striking freight train crew miss-interpreted a restricting signal as an approach indication, striking the stopped train. In addition to the damage of the striking and struck train, wreckage impacted and damaged two moving trains on the other two main tracks which both were moving in the same direction. No injuries where reported.

CAWG No. 24 Kingman, AZ 16-Sep-00
At 2245 hours, a freight train, with a two person crew, struck the rear of a stopped light engine consist while operating on double main in traffic control territory while an opposing train passed the site. The light power was stopped short of a signal, allowing the following striking train to believe the block was clear when they identified the next block as clear while not seeing the stopped locomotives in front of the clear signal. Three minor injuries were reported.

CAWG No. 25 Bellemont, AZ 31-Oct-00
At 1815 hours, a freight train, with a two-person crew, collided with the rear of a stopped freight train while operating on double track in traffic control territory. The engineer of the striking train reported the last signal he went by as being a grade signal with a clear indication. The conductor suffered fatal injuries and the engineer suffered serious injuries involving second and third degree burns, smoke and heat inhalation, along with shoulder, back and ankle injuries.

CAWG No. 26 Yarmony, CO 04-Nov-00

At 1410 hours, within traffic control territory, a coal train and an opposing light power consist were to meet at a siding. The light power consist, with a two person crew, entered the siding at 30 mph, reduced speed to 25 mph, then failed to stop for the signal displaying stop on the opposite end of the siding. After initiating an emergency application of the air brakes, the light engines impacted with the side of train passing on main track, derailing two locomotives and three coal cars. Two minor injuries were reported.

CAWG No. 27 Laredo, MO 20-Nov-00

At 0755 hours, a freight train with a two person crew, while operating on single main, traffic control territory, struck an opposing freight train as the opposing train was about to clear into a siding. Minor injuries were reported to the assistant engineer after he jumped from the train before impact.

CAWG No. 28 Murray, NE 18-Dec-00

At 1035 hours, a two-person freight-train crew collided with the rear of a stopped freight train while operating within TWC/ABS territory on single main track in extreme blizzard weather conditions. No injuries were reported.

CAWG No. 29 Kenner, LA 21-Dec-00

At 0415 hours, a two-person freight-train crew struck the side of an opposing freight train within a manual interlocking operated remotely by a dispatcher. Striking crew reported that the head light on the struck train temporarily blinded them, causing them to 'overshoot' the interlocking home signal. Two minor injuries were reported.

CAWG No. 30 Malden, TX 21-Dec-00

At 1555 hours, a three-person freight-train crew (engineer, conductor and student engineer), while operating in TWC/ABS territory collided head-on with a stopped train that was waiting in the siding for the striking train to pass. Siding switch was protected by a signal system and had not lined its self for main track movement before the arrival of striking train. Five minor injuries were reported.

CAWG No. 31 Woodburn, IA 27-Dec-00

At 1420 hours, a two-person crew, while operating on double main track within TWC/ABS territory, collided with the rear of a stopped freight train, while operating down a 0.6 percent descending grade. Two minor injuries were reported.

CAWG No. 32 Perkins, WY 22-Jul-99

At 0515 hours, a two-person coal train, operating in traffic control territory with cab signals traveling at 15 mph, struck a stopped coal train while ascending a .82 percent grade. No injuries were reported.

CAWG No. 33 Clinton, IA 11-Aug-99
At 1612 hours, a two person freight train crew, collided with the rear of a stopped freight while operating in yard limits and TWC territory killing the engineer and the assistant engineer of the striking train.

CAWG No. 34 Wickes, AR 13-Sep-99
At 0435 hours, a two person coal train, while operating in traffic control territory collided with the rear of a stopped coal train at 25 mph. Crew of the striking jumped from the locomotive shortly before the collision, resulting in the death of the conductor and minor injuries to the engineer.

CAWG No. 35 Cumberland, MD 20-Sep-99
At 1150 hours, a two person locomotive crew of a passenger train, struck the rear of a slowly moving freight train while operating in traffic control territory at 42 mph., in a curve with an obstructive view while descending a .22 percent hill. 32 passengers sustained minor injuries.

CAWG No. 36 Waldeck, KS 13-Nov-99
At 0001 hours, a two-person freight train crew collided head-on with another freight train that was stopped on the main track to meet the striking train. Both trains were operating in DTC/ABS territory. The switch at the meeting point was a hand-operated switch. Striking train passed over the meeting point switch and struck the standing train. The conductor of the striking train sustained minor injuries while exiting the locomotive before the collision.

CAWG No. 37 Fullerton, CA 18-Nov-99
At 0800 hours, a passenger train crew consisting of an engineer in the control cab and a conductor attending to duties with the passengers, collided with the side of an opposing freight train that was crossing over in triple main-traffic control territory. The collision resulted in 19 minor passenger injuries and one minor injury to the engineer of the striking train.

CAWG No. 38 Racine, MO 14-Jan-01
At 2320 hours, a two-person freight-train crew, operating in traffic control territory, struck the side of an opposing freight train that was entering a siding to meet the striking train. No injuries were reported. The conductor of the striking train tested positive on the required drug toxicology test.

CAWG No. 39 Carlisle, OH 17-Feb-01
At 0140 hours, a three-person freight-train crew (engineer, engineer pilot (operator) and conductor) while operating in single main-traffic control territory collided with the rear of a stopped freight train. The struck train's EOT was not functioning. Resulting collision led to the death of the engineer pilot and severe injuries to the conductor and engineer.

CAWG No. 40 Richmondville, NY 09-Apr-01

At 0645 hours, a two-person freight train, while operating in single main-traffic control territory, was struck by an opposing freight train (operating on the main track) after passing the absolute signal at the end of the siding. The struck train was to meet the striking train at this siding. All crew members jumped from the locomotives prior to the collision, resulting in one crew member suffering minor injuries.

CAWG No. 41 Glenwood, IA 18-Aug-01

At 1255 hours, a two-person freight-train crew struck the rear of a stopped freight train while operating in double main-traffic control territory. The grade was a descending .62 percent. Two minor injuries were reported.

CAWG No. 42 Ransom, IL 20-Aug-01

At 0848 hours, a two-person, freight-train crew struck the rear of a stopped freight train while operating in double main-track traffic control/ABS territory. The collision resulted in two minor injuries.

CAWG No. 43 Jacksonville, TX 07-Sep-01

At 1220 hours, a two-person freight-train crew collided with the rear of a stopped freight train. Both trains were operating in single main-traffic control territory. The resulting collision contributed to a release and explosion of a damaged car of phthalic anhydride. The conductor reported minor injuries.

CAWG No. 44 Hallsville, TX 11-Sep-01

At 0950 hours, a passenger train crew of three people (engineer was the only crew member on lead locomotive) collided with the side of a moving freight train at the end of a controlled siding in single main-traffic control territory while operating on the siding. Collision resulted in 12 injuries.

CAWG No. 45 Wendover, UT 13-Sep-01

At 0508 hours, a four-person passenger train crew, collided with an opposing two-person freight train on the main track. The freight train was pulling into the clear on the siding. The passenger train failed to comply with restrictive signals and hit the side of the freight train. Two employees and forty-one passengers were injured.

CAWG No. 46 Andersonville, MI 15-Nov-01

At 0553 hours, a two-person freight-train crew taking siding to meet an opposing two-person freight train, which was to hold the main track, failed to take any action to stop in the clear at the end of the siding and reoccupied the main track. It was struck head-on by the opposing train, killing both its crew members.

CAWG No. 47 Mayfield, OH 08-Dec-01

At 2350 hours, a two-person freight train failed to comply with restrictive signals and struck the rear end of a two-person standing freight train ahead of them on the same main track. All three locomotives of the striking train derailed, but remained upright. There were no injuries sustained in this rear end collision.

CAWG No. 48 Swenney, TX 06-Dec-02

At 0645 hours, a two person freight train crew holding the main track at a meet failed to comply with restricting signals and then passed a stop signal at the far end of the siding and struck the opposing two man freight train which was taking siding. All four employees sustained injuries.

CAWG No. 49 Pacific, MO 12-Dec-01

At 0545 hours, a two-person freight train failed to comply with restrictive signals and struck the rear end of a stopped two-person freight train ahead. The resulting derailed cars and engines fouling the adjacent track then derailed an opposing two-person freight train on that track. One employee was injured.

CAWG No. 50 Kenner, LA 15-Dec-01

At 0415 hours, a two-person freight train failed to comply with a stop signal displayed at an interlocking associated with a drawbridge and collided with the side of an opposing two-person freight train transiting the interlocking. One employee was injured.

CAWG No. 51 Bradford, IL 01-Jan-02

At 2346 hours, a southbound two person freight train failed to stop on the main track in the clear at the end of authority in track warrant territory and struck the side of an opposing two person freight train that was taking siding. One employee on the southbound train sustained injuries.

CAWG No. 52 La Porte, IN 03-Feb-02

At 0335 hours, an eastbound two-person freight train running on an Approach signal failed to stop in the clear of the home signal at a crossover and collided with an opposing two-person freight train entering the crossover to pass on the second main track. All four crew members on the two colliding trains sustained non-fatal injuries.

CAWG No. 53 Placentia, CA 23-Apr-02

At 0816 hours, an eastbound two-person freight failed to comply with Approach and Stop signals and struck an opposing two-person-crew passenger train head-on that was entering the interlocking for a diverging route. All four crew members of the two trains sustained injuries. Two passengers were killed and 163 passengers were injured.

CAWG No. 54 Douglas, WY 11-May-02

At 0753 hours, a two person westbound freight train collided with an opposing two-person freight train on the same track in two main territory after the former failed to comply with the stop indication given to them at the interlocking signal. All four crew members of the two freight trains sustained injuries.

CAWG No. 55 Clarendon, TX 28-May-02

At 0856 hours, eastbound two person freight train failed to comply with track warrant and collided head on with a two person opposing intermodal freight train, killing one employee and injuring the remaining three.

CAWG No. 56 Aurora, IL 12-Jun-02

At 1521 hours, an eastbound four employee commuter train failed to comply with a stop signal, trailed through an opposing power switch, and collided head-on with a westbound four employee passenger train. Five employees and forty-three passengers sustained injuries.

CAWG No. 57 Leesburg, TX 16-Jun-02

At 0440 hours, a two person freight train failed to comply with signal indications, including stop signal, and struck the rear-end of a two person freight train that was stopped ahead of them. One crew member of the striking train sustained non-fatal injuries.

CAWG No. 58 Baltimore, MD 17-Jun-02

At 0541 hours, a three employee passenger train passed a stop signal at an interlocking and collided with the side of a four employee passenger train in the interlocking that was going in the same direction. Five employees and three passengers on the two passenger trains sustained injuries.

CAWG No. 59 North Platte, NE 19-Jun-02

At 0415 hours, a two-person freight train failed to comply with a stop signal and collided with the rear end of a two-person freight train stopped ahead on the same track. An opposing two-person freight train on the adjacent main track collided with the derailed equipment, resulting in an additional derailment. One employee on the striking train and one employee on the opposing train that struck the derailed equipment sustained injuries.

CAWG No. 60 Jamaica, NY 22-Jun-02

At 1157 hours, a four-employee passenger train operating on a "restricting" signal failed to stop before colliding with a six-employee passenger train had stopped on the same track. Three employees and sixty-seven passengers were injured as a result of this rear end collision.

CAWG No. 61 San Bernardino, CA 30-Jun-02

At 1310 hours, a two-person freight train following another two-person freight train on the same track under a restricting signal failed to realize that the train ahead had stopped. The striking train could not stop before colliding with the rear of the stopped freight train ahead. There were no injuries. Four cars of the struck train derailed.

CAWG No. 62 Vader, WA 15-Sep-02

At 0120 hours, eastbound two-person freight train failed to comply with a stop signal and struck the rear of a two person eastbound freight train that was stopped ahead on the same track. One employees sustained injuries.

CAWG No. 63 Reddick, IL
10-Oct-02
At 0830 hours, an eastbound two person freight train operating in track warrant territory struck a stopped two person opposing freight train waiting in the clear at the west end of the siding when the crew member of the train in the siding failed to correctly line the switch for the main track. Three employees were injured in the head-on collision.

CAWG No. 64 Des Plaines, IL 21-Oct-02
At 2238 hours, a northbound two-person freight train failed to comply with a stop signal at an interlocking and collided with the side of a southbound two-person freight train that was transiting the interlocking. The two employees on the striking train sustained injuries.

CAWG No. 65 Valley Pass, NV 05-Nov-02
At 0145 hours, a two person intermodal freight on the main track failed to comply with a stop signal at the end of the siding and collided with the side of a two person freight unit train that was pulling out of the siding onto the main track to go in the same direction as the striking train. There were no injuries.

2.4 Qualifying Collisions in 2003 and 2004

There are 13 collisions in 2003 and 18 in 2004 resulting in 8 fatalities (6 employees and 2 non-trespassers) meeting CAWG's review criteria. The 2003 investigations were not complete when the review of these 65 cases was finished. Extending the publication date of this study would unduly delay this collision-avoiding information from reaching the railroad industry. CAWG's intent is to ensure subsequent main-track train collisions will be added to the CAWG Database, thereby allowing for continuous, up-to-date analysis. CAWG views collision prevention efforts, using the methods of this study, as ongoing.

Preliminary case descriptions of the 31 qualifying collisions occurring in 2003 and 2004, pending review, are listed below:

2003 Main-Track Train Collisions

1. Philadelphia, PA 25-Jan-03
A northward freight train, operating at 24 mph, struck the rear end of a standing freight train.

2. Brush, CO 02-Mar-03
A westward coal train, operating at 16 mph, struck the rear end of a standing coal train.

3. Seattle, WA 10-Mar-03
A freight train, operating at 18 mph, struck the side of an opposing train.

4. Ashtabula, OH 11-Mar-03
A freight train, operating at 7 mph, collided head-on with a standing train.

5. Seattle, WA **02-May-03**
A freight train, operating at 5 mph, struck the rear-end of another train.

6. Flomaton, AL **04-May-03**
A freight train, operating at 20 mph, struck the rear-end of another train.

7. Matfield Green, KS **17-May-03**
An eastbound freight train, struck the side of a westbound freight train.

8. Cumberland, MD **19-Jun-03**
A westbound container train, operating at 28 mph, collided head-on with a freight train operating at 11 mph.

9. Bisbee, TX **28-Jul-03**
A freight train, operating at 20 mph, collided head-on with a standing train.

10. Chriesman, TX **17-Sep-03**
A freight train, operating at 13 mph, struck the rear-end of another train.

11. Baltimore, MD **18-Sep-03**
A freight train, operating at 7 mph, collided head-on into a standing train.

12. Longview, WA **15-Nov-03**
An intermodal train, operating at 50 mph, struck the side of an intermodal train.

13. Pauls Valley, OK **29-Dec-03**
A westbound train, traveling at 4 mph, struck the side of an eastbound train traveling at 14 mph.

2004 Main-Track Train Collisions

1. Carrizozo, New Mexico **21-Feb-04**
A freight train, operating at 36 mph, struck the side of a loaded grain train as the grain train entered the siding to clear the main track. Both crew members of the striking train were killed.

2. Hesperia, CA **28-Apr-04**
A freight train, operating at 18 mph, struck the side of a freight train operating at 8 mph, resulting in derailed cars and closed highways.

3. San Antonio, TX **03-May-04**
A westbound freight train operating at 40 mph struck the side of the last car of an eastbound freight train, as the eastbound train was crossing over from one main track to another.

4. North Dexter, MO **07-May-04**

A northward freight train, operating at an estimated 16 mph, struck the rear of a standing northward intermodal train.

5. Surgoinsville, TN **14-May-04**
An eastward loaded coal train, operating at an estimated 40 mph, struck the rear of a standing eastward freight train.

6. Gunter, TX **19-May-04**
A southward freight train, operating at an estimated 40 mph, collided, head-on, with a northward freight train. One employee was killed and four were injured.

7. Gurdon, AR **24-May-04**
A northward freight train, operating at an estimated 30 mph, struck the rear of a standing northward intermodal train.

8. Front Royal, VA **27-May-04**
A westward intermodal train, operating at an estimated 19 mph, struck the rear of a standing westward freight train.

9. Morton, MS **07-Jun-04**
A westward freight train, operating at an estimated 24 mph, failed to stop and struck the side of an eastward freight train.

10. Bloom, UT **19-Jun-04**
An eastward freight train, operating at an estimated 7 mph, struck the side of a westward freight train as it was entering the siding.

11. Saugerties, NY **27-Jun-04**
A northward freight train, operating into a siding at an estimated 11 mph, struck the rear of a standing northward freight train that was waiting for an opposing train to arrive.

12. MacDona, TX **28-Jun-04**
A westward freight train, operating at an estimated 45 mph, failed to stop and struck the side of an eastward freight train while it was entering the siding. A chlorine leak ensued, an evacuation was ordered. The conductor and two citizens were found dead at the scene.

13. Baltimore, MD **10-Oct-04**
An eastward freight train, operating at 18 mph, struck the side of another freight train that was crossing over from one main track to another.

14. Zita, TX **02-Nov-04**
A freight train, operating at 6 mph, struck the rear of a standing intermodal train.

15. Vitis, FL **29-Nov-04**
A southward freight train collided head-on with a northward freight train. As a result, two employees were hurt and one was killed.

16. Niland, CA **10-Dec-04**

An eastward freight train, operating at 30 mph, collided head-on with a westward freight train operating at 10 mph. As a result of the collision, 1 crew member was killed and 4 were injured.

17. Drury, TX **20-Dec-04**

A northward freight train, operating at 24 mph, passed a “stop and proceed at restricted speed” signal and struck the rear car of a standing northward train.

18. Greencastle, PA **20-Dec-04**

A southward freight train, operating at restricted speed and pulling into a siding, was struck in the side by a northward train operating at 21 mph.

3. DESCRIPTIVE OVERVIEW

3.1 Understanding Causes of Main-Track Train Collisions

This section contains descriptions and tables of selected attributes of the 65 main-track train collisions. Data description is the sole purpose of this section. These attributes include: collision type, year, month, weekday, daylight condition, visibility, weather, casualty counts, damage, speed, hazmat release, and track density. Displaying these attributes begins the process of understanding the causes of these collisions – both what is, and is not, involved. Many of the collision attributes presented tend to rule out at the general level – as opposed to confirm – possible causes.

Collision type

The collision type for 31 of the 65 collisions was rear-end – 48 percent – as shown in Table 3-1. There were 18 side collisions: 13 head-on; and 3 at railroad crossings.

Table 3-1. Type of Collision, 1997 through 2002

Collision Type	Count	Percent
rear end	31	47.7
side	18	27.7
head on	13	20.0
railroad grade crossing	3	4.6
total	65	100.0%

Year

On average 10.8 main-track train collisions occurred per year over the six-years, 1997 to 2002. The number of main-track train collisions fluctuated yearly from a low of 4 in 1998 to a high of 16 [20] in 2002, as shown in Table 3-2. CAWG draws no conclusion as to whether the number of main-track train collisions are increasing over the six-year period, or just fluctuating randomly about the average of 10.8 collisions, with the 1998 count of 4 being an unusually low value (outlier). However, by arranging main-track train collisions on a time-series basis, and noting the average and the average variation (about 4.0 collisions), a structure is created to help evaluate whether *absolute* changes in the number of collisions are occurring over time – and to what extent the findings and recommendations made in this study, along with government and industry safety efforts, have affected such change.

[20] The standard deviation, a measure of the average variation about the mean, is 3.97 collisions. The medium is 11 collisions, almost identical to the average (10.8), indicating the distribution in the number of collisions per year is slightly skewed to the left, but essentially normal.

Table 3-2. Collisions by Year, 1997 through 2004

Year	Yearly Count	Rear End	Side	Head On	Railroad Grade Crossing
1997	11	6	2	2	1
1998	4	3	0	0	1
1999	11	6	2	2	1
2000	10	5	4	1	0
2001	13	7	4	2	0
2002	16	4	6	6	0
*2003	13	5	4	4	0
*2004	18	7	8	3	0
total	96	43	30	20	3

* 2003 and 2004 collision cases were not reviewed, but are included here with the 1997 through 2002 cases for trend-comparison purposes. All years were selected by the same main-track, human-factor criteria.

Month

During the six-year period of CAWG's review, 1997 through 2002, monthly collisions ranged from 3 in five of the months to a high of 10 in September followed by 9 in November and 8 each in December and June as shown in Table 3-3.. The average monthly number of collisions is 5.4; the medium, 4.0.

Note: In the Findings, Discussion, and Recommendation section, two periods of heightened risk during the year are identified. While there is always risk, employees should be aware of these periods.

Table 3-3. Collisions by Month, 1997 through 2002

Month	Count	Percent
JAN	3	4.6
FEB	3	4.6
MAR	4	6.2
APR	3	4.6
MAY	3	4.6
JUN	8	12.3
JUL	4	6.2
AUG	3	4.6
SEP	10	15.4
OCT	7	10.8
NOV	9	13.9

DEC	8	12.3
total	65	100.0%

Weekday

As shown in Table 3-4, there was one main-track train collision on Fridays, compared to 15, 13, and 13 respectively on Mondays, Thursdays, and Saturdays. CAWG did not establish why variation existed among days of the week, and particularly why the count on Friday was relatively low.

Table 3-4. Collisions by Day of Week, 1997 through 2002

Month	Count	Percent
Sunday	8	12.3
Monday	15	23.1
Tuesday	8	12.3
Wednesday	7	10.8
Thursday	13	20.0
Friday	1	1.5
Saturday	13	20.0
total	65	100.0%

Time

Table 3-5 shows the frequency of collisions by hour of day. The highest number of collisions (8) occurred between 4:00 am and 5:00 am. The second highest number of collisions (6) occurred between 8:00 am and 9:00 am. The fewest collisions (0) occurred between 7:00 pm and 8:00 pm. One collision occurred between 2:00 am and 3:00 am; 9:00 am and 10:00 am; 4:00 pm and 5:00 pm; 8:00 pm and 9:00 pm; and 9:00 pm and 10:00 pm.

Table 3-5. Collisions by Hour of Day, 1997 through 2002

	Hour of Day	Count	Percent of 65 Collisions		Hour of Day	Count	Percent of 65 Collisions
AM	**1**	3	4.6	**PM**	**1**	2	3.1
	2	5	7.7		**2**	2	3.1
	3	1	1.5		**3**	3	4.6
	4	2	3.1		**4**	3	4.6
	5	8	12.3		**5**	1	1.5
	6	4	6.2		**6**	3	4.6
	7	2	3.1		**7**	2	3.1
	8	3	4.6		**8**	0	0.0

9	6	9.2	**9**	1	1.5
10	1	1.5	**10**	1	1.5
11	4	6.2	**11**	2	3.1
12	3	4.6	**12**	3	4.6
totals	42	64.6%		23	35.4%

Daylight condition

Collisions occurred nearly equally between day and dark, 33 v. 28 collisions (51 v. 43 percent), as shown in Table 3-6. There were 3 collisions at dawn and 1 at dusk.

Table 3-6. Collisions by Daylight Conditions, 1997 through 2002

Daylight Condition	Count	Percent
Day	33	50.8
Dark	28	43.1
Dawn	3	4.6
Dusk	1	1.5
	65	100.0%

Weather

Stormy weather was not generally a Possible Contributing Factor (PCF), as shown in Table 3-7. CAWG used weather-related PCFs in three cases (CAWG Nos. 11, 18, and 48). Fifty-nine percent of the 65 collisions occurred in clear visibility. Twenty-five percent occurred in cloudy visibility; and 17 percent occurred in rain, fog, and snow.

Table 3-7. Collisions by Weather, 1997 through 2002

Visibility	Count	Percent
Clear	38	58.5
Cloudy	16	24.5
Rain	4	6.2
Fog	5	7.7
Snow	2	3.1
	65	100.0%

Casualty

The 65 collision cases are ‘accidents’ in the sense that physical damage well exceeded the Federal Railroad Administration reporting thresholds. CAWG emphasizes main-track train collisions are often associated with human casualty as shown in Table 3-8. The 65 main-track train collisions resulted in 16 total fatalities and 531 injuries. There were 14 employee fatalities and 128 employee injuries; 2 passenger fatalities and 403 passenger injuries.

Table 3-8. Collisions by Casualty Type, 1997 through 2002

Type	Fatalities	Injuries	Total Casualty
Employees	14	128	142
Passengers	2	403	405
total	16	531	547

One passenger collision in Placentia, CA (No. 39), accounted for all of the passenger (2) fatalities and 163 passenger injuries.

Property Damage

The amount of property damage in the 65 main-track train collisions varied (Table 3-9). The most damage in one collision (Pacific, MO, No. 49) was $7,855,920. Track and switch, lading, and equipment damage in the 65 collision cases totaled $83,108,072, an average of $1,278,586 per collision (Table 3-10). Eighty-five percent of total property damage is to equipment.

Table 3-9. Frequency of Lading, Track and Switch, and Equipment Damage, 1997 through 2002

Total Damage ($millions)	Count	Percent
0.0 – 0.09	7	10.8
0.1 – 0.40	17	26.2
0.5 – 0.90	16	24.5
1.0 – 1.90	15	23.1
2.0 – 4.90	7	10.8
5.0 – 7.80	3	4.6
total	65	100.0%

Table 3-10. Value of Lading, Track and Switch, and Equipment Damage, 1997 through 2002

Damage Type	Total $	Percent	Average $ per Collision
Lading	2,299,500	2.8	35,377
Track and Switch	10,142,905	12.2	156,045
Equipment	70,665,667	85.0	1,087,164
total	$83,108,072	100.0%	$1,278,586

Hazmat

There were 42 hazardous material cars derailed with four hazmat releases (Table 3-11).

Table 3-11. Hazmat Summary for Collisions, 1997 through 2002

CAWG No.	Location	Date	Striking Train	Struck Train	Count of Hazmat Cars Derailed	Count of Cars Releasing Hazmat
1	Kenefick, KS	07/02/97		yes	14	0
43	Jacksonville, TX	09/07/01		yes	7	1
7	St. Albans, WV	06/07/97		yes	5	1
48	Swenney, TX	12/01/02		yes	5	0
12	Navasota, TX	10/29/97	yes		4	0
18	Stryker, OH	01/17/99	yes		2	2
23	Cincinnati, OH	09/04/00	yes		1	0
25	Bellemont, AZ	10/31/00	yes		1	0
25	Bellemont, AZ	10/31/00		yes	1	0
37	Fullerton, CA	11/18/99		yes	1	0
52	La Porte, IN	02/03/02		yes	1	0
		total	5	7	47	4

Speed at impact

Table 3-12 indicates the frequency of traveling speeds for both the violating and non-violating trains.

Table 3-12. Collisions by Speed, 1997 through 2002

Speed Category (mph)	Violating Train	Percent	Non-Violating Train	Percent
0 – 10	13	19.7	44	64.7
11 – 20	18	27.3	13	19.1
21 – 30	21	31.8	8	11.8
31 – 40	14	21.2	3	4.4
total	66	100.0%	68	100.0%

Tack density

Table 3-13 shows the annual track density in millions of gross tons for collision location.

Table 3-13. Collisions by Annual Track Density (millions of gross tons), 1997 through 2002

Track Density	Count	Percent
less than 16	16	29.0
16 – 50	18	27.7
greater than 50	21	38.2
total	*55	100.0%

* Track density not available for all 65 collisions.

FRA track type

Table 3-14 shows the distribution of collisions by FRA track type.

Table 3-14. Collisions by FRA Track Type, 1997 through 2002

FRA Track Class	Definition of FRA Track Class	Count	Percent
1	1=10 mph freight, 15 mph passenger trains	2	3.1
2	2=25 mph freight, 30 passenger trains	9	14.1
3	3=40 mph freight, 60 passenger trains	13	20.3
4	4=60 mph freight, 80 passenger trains	32	50.0
5	5=80 mph freight, 90 passenger trains	8	12.5
	total	*64	100.0%

* FRA Track Class not available for all 65 collisions.

Train length

Table 3-15 shows the distribution of collisions by train length.

Table 3-15. Main-Track Train Collisions by Train Length, 1997 through 2002

Train Length (feet)	Violating Trains	Percent	Non-Violating Trains	Percent
Under 4000	16	28.1	10	16.4
4000 – 5999	17	29.8	23	37.7
6000 and over	24	42.1	28	45.9
total	*57	100.0%	*61	100.0%

* Train length was not available for all trains involved in the 65 collisions.

Time on duty

Table 3-16 shows the distribution of collision by time on duty for both the crew of the violating and non-violating trains.

Table 3-16. Time on Duty for Crew Members of Violating and Non-Violating Trains

Time on Duty (hours)	Violating Train	Percent	Non-Violating Train	Percent
under 3	37	25.7	16	13.3
3 – 5:59	64	44.4	47	39.2
6 – 8:59	30	20.8	37	30.8
over 9	13	9.0	20	16.7
total	144	100.0%	120	100.0%

4. REVIEW AND ANALYTICAL METHODS

4.1 Overview

This section presents collision concepts and analytical aids CAWG used to review and analyze the 65 main-track train collisions, and to make findings and recommendations based on the commonality of facts among collisions. Information contained in this section – including the Findings, Discussions, and Recommendations – is based solely on review and analyses of 65 main-track train collisions occurring from 1997 through 2002. CAWG did not consider results of other investigations, reviews, and analyses of main-track train, or other types of collisions. CAWG results are specific to its data.

CAWG's causality concept is based on identifying all of the possible contributing factors for each collision without ranking the factors in importance. Ranking often involves subjective judgment, creates difficulty in gaining consensus, and is simply not necessary if the purpose is identifying commonalities. CAWG's collision causality approach is well suited to its purpose of finding commonalities among collisions so collision-preventive recommendations can be made and expediently implemented.

4.2 CAWG Database

Initially, CAWG recorded data from its review and discussion of the first 27 collision cases (CAWG No.s 1-27) in Microsoft® Excel files, one workbook per case with multiple spreadsheets for general, locomotive and equipment, crew, and consensus information. Although the spreadsheet files provided a well-structured approach for recording information, CAWG realized this method would not provide a rapid and practical method of searching for commonalities across cases once information from all 65 collisions was entered.

Anticipating rapid information retrieval would be essential to developing accurate findings and recommendations, CAWG obtained expert technical support to develop a software database system using Microsoft® Access to address the retrieval shortcomings of the spreadsheet approach. The Access database became known as the 'CAWG Database.' The information for the 27 cases in Excel workbook files was 'rolled over' into the CAWG Database. All subsequent reviews were entered into the CAWG Database.

The CAWG Database is a permanent resource to reside in the Federal Railroads Administration's Office of Safety, available to the railroad-safety community studying main-track train collisions and responding to new collision events with the need for background information. Future collision reviews by CAWG, or other safety groups, can be appended to the 65 collision cases, creating an even richer repository of collision information.

4.3 Distinguishing Violating and Non-Violating Trains

One of the first analytical decisions CAWG made in reviewing each collision case was determination of which train or trains was likely at fault. In 64 of the collision cases, one of the trains was determined to be the *violating train*. In the other collision case (North Bay, CA, No. 8), both trains involved were designated as *violating trains*. Thus, there were 65 collision cases and 66 violating trains.

Of the 66 violating trains, 59 were considered the striking train by CAWG, and 7 were considered struck. Table 4-1 shows the violating trains by consist type, 82 percent being freight.

Table 4-1. Violating Trains in Main-Track Train Collisions by Consist Type, 1997 through 2002

Consist Type	No.	Percent
Freight	54	81.8
Passenger	6	9.1
Commuter	3	4.6
Light locomotives	2	3.0
Unattended cars	*1	1.5
Total	**66	100.0%

* Cars occupied the main track in violation of track warrant authority.
** Sums to 66 because one collision (CAWG No. 8) had two violating trains.

4.4 Approach to Alertness

CAWG adopted a data driven approach that focuses on observable behaviors of alertness, i.e., attention to and appropriate responses to one's surroundings rather than the less exact term *fatigue* that has various meanings for different people. CAWG used judgments of a sleep expert to estimate the cumulative amount of sleep employees could have received before going on duty. The expert corroborated CAWG's independent alertness evaluations. Alertness, and its analytical methods, are discussed in the Findings, Discussion, and Recommendation section.

4.5 CAWG's Approach to Causality

Historically, the railroad industry has reported collisions as due to one cause. However, rarely are main-track train collisions the result of a single factor or cause. Review of the 65 collisions clearly establishes that most collision events are a combination of unrelated factors and deviations occurring at the same time, at the same location, and on the same train. Sometimes, these factors and deviations do not rise to the level of identifiable violation of operating regulations and/or standards. The greater the number of factors and deviations present, the more likely is a collision.

The cases reviewed by CAWG appear to involve human error. CAWG's style of research and review regarded human error in a way similar to Dekker (2002): "human error is systematically connected to features of people's tools, tasks, and operational/organizational environment."[21] CAWG approached the cases with an attitude described by Dekker: "The new view of human error wants to understand why people made the assessments or decisions they made – why these assessments or decisions would have made sense from the point of view inside the situation." [22]

CAWG developed an approach to collision causality based on consideration of an often complex combination of rail-system operating characteristics, conditions, and events. CAWG in determining causality does not attempt to rank these factors, usually expressed as Possible Contributing Factors (PCFs). The SOFA effort demonstrated how PCFs can empower the railroad industry to identify and address specific issues where risks and exposures can be further reduced. CAWG views causality as a web of interrelated factors. CAWG found that collisions do not result from chance, randomness, or bad luck.

CAWG used the FRA's *Train Accident Cause Codes*[23] and its own defined codes as the basis for PCFs. Each collision was assigned as many PCFs as CAWG believed applied; however, the number of PCFs applied to a collision case did not go beyond the number necessary to capture the essence of the identified factors. CAWG avoided redundancies, and causal information not appropriately captured by a PCF was described in narrative form.

4.6 Human Factor Possible Contributing Factors

Possible Contributing Factors (PCF) for the 65 collisions involve human factor issues: alertness, which can be degraded by temporary and chronic lack of sleep, circadian rhythm phasing, drugs (both prescription and illegal), alcohol, and boredom; operating capability contingent on training, experience (both general railroad knowledge and that specific to a territory), and judgment; and crew utilization, involving crew resource management.

Only one collision is assigned a PCF for a known signal failure; and three collisions are assigned mechanical PCFs. This does not mean signal and mechanical failures are the sole cause of those collisions – only a PCF. Weather is not generally a PCF consideration. CAWG used weather-related PCFs in three cases (CAWG Nos. 11, 18, and 48), otherwise weather is not a factor. Drugs and alcohol are not generally factors. CAWG used H101 – *Impairment of efficiency or judgment because of drugs or alcohol*, as a PCF in two cases (Nos.12 and 40).

4.7 Overall Frequency of Possible Contributing Factors

In reviewing the 65 main-track train collision cases, CAWG used 37 different PCF codes. As shown in Table 4-2, H215 – *Block signal, failure to comply*, used in 31 collision

[21] Dekker, S. (2002). The Field Guide to Human Error Investigations. *Ashgate*: Burlington, VT. p. vii.
[22] ibid, p. 64.
[23] Contained in Appendix C, pages 1-11, of the *FRA Guide for Preparing Accident/Incident Report*. Federal Railroad Administration. 1997.

cases; and H216 – *Interlocking signal, failure to comply* are the most frequently applied PCFs as would be expected since most of the collisions involve signal non-compliance. H605 – *Failure to comply with restricted speed*, the third most frequent PCF, is used in 12 cases (18.5 percent). On average, CAWG used 2.5 PCFs per collision.

Table 4-2. Frequency of Possible Contributing Factors (PCFs) in 65 Main-Track Train Collisions, 1997 through 2002

1	H215	Block signal, failure to comply	30
2	H216	Interlocking signal, failure to comply	28
3	H605	Failure to comply with restricted speed	12
4	H989	Lack of skill or practical wisdom gained by personal knowledge or action	11
5	H104	Employee asleep	10
6	H316	Poor Intra-crew communication	10
7	H999	Other train operation/human factors	6
8	H318	Poor crew utilization	5
9	H204	Fixed signal, failure to comply	6
10	H199	Employee physical condition, other	3
11	H317	Failure to communicate unsafe condition	3
12	H398	Poor Inter-crew communication	3
13	H404	Train order, track warrant, track bulletin, or timetable authority, failure	3
14	M104	Extreme environmental condition – dense fog	3
15	E03C	Obstructed brake pipe (closed angle cock, ice, etc.)	2
16	H499	Other main track authority causes	2
17	H101	Impairment of efficiency or judgment because of drugs or alcohol	2
18	H603	Train inside yard limits, excessive speed	2
19	H702	Switch improperly lined	2
20	H299	Other signal causes	1
21	E03L	Obstructed brake pipe (closed angle cock, ice, etc.) locomotive	1
22	H099	Use of brakes, other	1
23	M199	Other extreme environmental conditions	1
24	H203	Fixed signal improperly displayed	1
25	H992	Operation of locomotive by uncertified/unqualified person	1
26	H211	Radio communication, improper	1
27	H212	Radio communication, failure to give/receive	1
28	H401	Failure to stop train in clear	1
29	H799	Use of switches, other	1
30	H510	Automatic brake, insufficient (H001) – see note after cause H599	1
31	H307	Shoving movement, man on or at leading end of movement, failure to control	1
32	H604	Train outside yard limits under clear block, excessive speed	1
33	S099	Other signal failures (Provide detailed description in narrative)	1
34	H599	Other causes relating to train handling or makeup	1
35	H502	Improper placement of cars in train between terminals	1
36	H509	Improper train inspection	1
37	H991	Tampering with safety/protective device(s)	1

4.7 Frequency of Codes Used with H215 and H216

PCF code H215 was used in 31 main-track train collision cases; and H216, in 28 cases. To be expected, these PCF were the most frequently used as mentioned above. While these two codes indicate the act, other PCF codes are needed to indicate the why. Tables 4-3 and 4-4 show the frequency of other PCF codes used with respectively H215 and H216.

Table 4-3. H215 – *Block Signal Failure to Comply*: Other PCFs Used with H215, by Collision Count

PCF	Collision Count	PCF	Collision Count
H216-Interlocking signal, failure to comply	9	H318-Poor crew utilization	1
H104-Employee asleep	6	H499-Other main track authority causes	1
H989-Lack of skill or practical wisdom gained by personal knowledge or action	5	H603-Train inside yard limits, excessive speed	1
H605-Failure to comply with restricted speed	3	H702-Switch improperly lined	1
H316-Poor Intra-crew communication	3	H799-Use of switches, other	1
M104-Extreme environmental condition – dense fog	3	H991-Tampering with safety/protective device(s)	1
H510- Automatic brake, insufficient (H001) – see note after cause H599	1	H992-Operation of locomotive by uncertified/unqualified person	1
H203- Fixed signal improperly displayed	1	H999-Other train operation/human factors	1
H299- Other signal causes	1	H398-Poor Inter-crew communication	1

Table 4-4. H216 (Interlocking Signal, Failure to Comply): Other PCFs Used with H216, by Collision Count

PCF	Collision Count	PCF	Collision Count
H215-Block signal, failure to comply	9	H101-Impairment of efficiency or judgment because of drugs or alcohol	2
H989-Lack of skill or practical wisdom gained by personal knowledge or action	5	H203-Fixed signal improperly displayed	1
H999-Other train operation/human	4	H204-Fixed signal, failure to comply	1
H104-Employee asleep	4	H398-Poor Inter-crew communication	1
H316-Poor Intra-crew communication	4	H502-Improper placement of cars in train between terminals	1
H318-Poor crew utilization	3	H510-Automatic brake, insufficient (H001) – see note after cause H599	1
H605-Failure to comply with restricted speed	3	H603-Train inside yard limits, excessive speed	1
H199-Employee physical condition, other	3	H604-Train outside yard limits under clear block, excessive speed	1
M104-Extreme environmental condition – dense fog	2	H317-Failure to communicate unsafe condition	1

4.8 Collisions Cases Without H215 and H216

H215 and H216 were used in 59 main-track train collision cases. H605 **–** F*ailure to comply with restricted speed* was used in the remaining 6 collision cases to indicate the main act resulting in the collision. While these three codes indicate the act, other codes are needed to indicate the why. Table 4-5 lists the PCFs used with H605.

Table 4-5. Main-Track Train Collision Cases with H605 – *Failure to comply with restricted speed* – Where H215 and H216 Were Not Used, 1997 through 2002

CAWG No.	8	13	28	33	60	61
H605-Failure to comply with restricted speed	1	1	1	1	1	1
H204-Fixed signal, failure to comply		1				
H212-Radio communication, failure to give/receive		1				
H307-Shoving movement, man on or at leading end of movement, failure to control		1				
H318-Poor crew utilization		1				
H398-Poor Inter-crew communication				1		
H404-Train order, track warrant, track bulletin, or timetable authority, failure	1			1		
H989-Lack of skill or practical wisdom gained by personal knowledge or action	1					
H999-Other train operation/human factors		1				
M199-Other extreme environmental conditions			1			

4.9 PCF Definition of H989

CAWG uses Possible Contributing Factor (PCF) H989 – *Lack of skill or practical wisdom gained by personal knowledge or action* when an individual crew member's performance exhibits a lack of practical understanding of a particular situation. Consideration going into the use of H989 includes: training, experience, and circumstances unique to each collision. CAWG used H989 11 times, as shown in Table 4-6. There are 10 collision cases (15.4 percent of 65 collisions) where H989 is particularly influential in collision events.

Table 4-6. Eleven Main-Track Train Collisions with PCF H989 – *Lack of skill or practical wisdom gained by personal knowledge or action,* 1997 through 2002

CAWG No.	Location	Date
2	Jacksonville, FL	July 1, 1999
4	Alvord, TX	November 3, 1997
6	Lagro, IN	May 31, 1997
8	North Bay, CA	October 16, 1997
15	Butler, IN	March 23, 1998
17	Orin, WY	September 12, 1998
19	Momence, IL	March 23, 2003
34	Wickes, AR	September 13, 1999
42	Ransom, IL	August 20, 2001
51	Bradford, IL	January 1, 2002
58	Baltimore, MD	June 17, 2002

4.10 Philosophy of Collision Avoidance

James Reason created the Swiss Cheese Model[24] to demonstrate the multiple defenses (barriers, rules, procedures, systems, training, communications) set up to prevent human-factor accidents like the 65 main-track train collisions. A representation of his model is shown in Figure 4-1. Only when a "straight shot" is created to the target through all the barriers does a human-factors collision occur.

[24] James Reason, 1997, *Managing The Risks of Organizational Accidents*

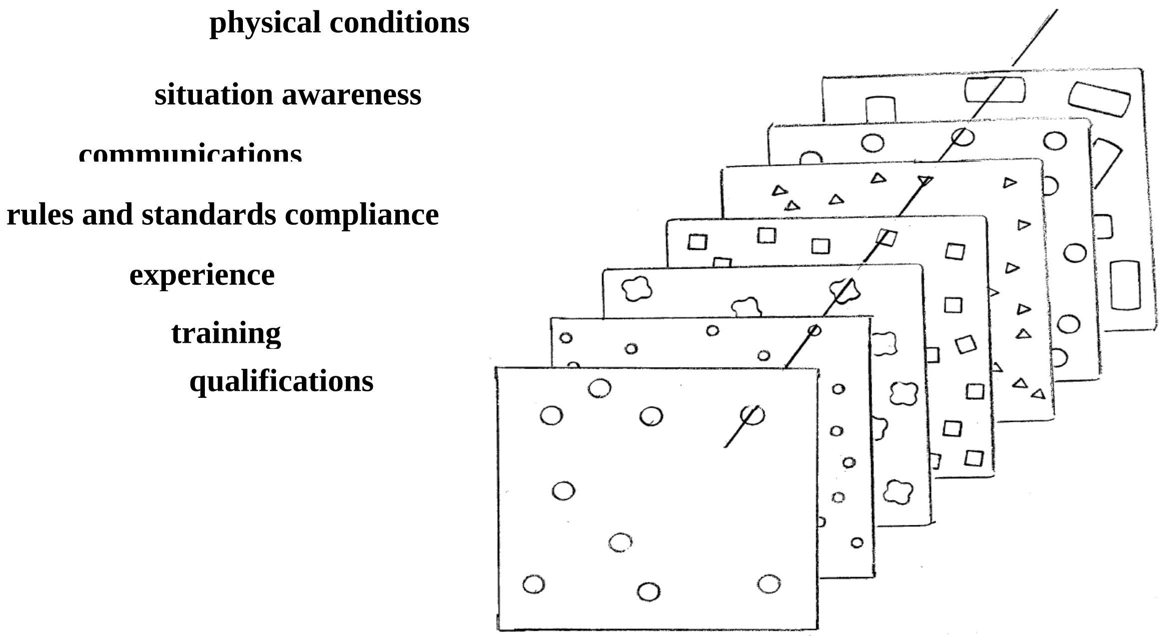

Figure 4-1. Swiss Cheese Model of Collision Causation.

The Swiss Cheese Model helps in demonstrating myths about collisions. First, collisions usually involve several factors. Rarely are collisions the result of a single cause. CAWG has carried over from its work in Switching Operations Fatality Analysis (SOFA) the concept of a sequence of events leading up to, in its case, a switching fatality, which often involves human-factor issues. To describe the switching-fatality process, SOFA used the same Possible Contributing Factors (PCFs) approach that CAWG is using to analyze the 65 main-track train collisions. SOFA rejected the more restrictive, and less amenable to prevention, idea of a single *cause*. SOFA demonstrated the use of PCFs can empower the railroad industry to identify and address specific issues where risks and exposures can be further reduced.

The second collision myth is that only primary causes are important. Rather, CAWG believes only by focusing on *all* causes can complete prevention be achieved. The experience of Chuck Yeager is instructive. The legendary pilot believes that his greatest aviation accomplishment was not his decorated military career, or his test pilot experience, or even his world flight records. Chuck Yeager is most proud of his role in reducing military air flight catastrophes by focusing on finding *all* causal areas.

The third myth is for a collision to take place there must necessarily be a direct violation of FRA, AAR, ASLRRA and/or carrier operating rules. Not true. Rules and standards cannot cover every operational situation and contingency. And, importantly, rules and standards cannot always account for combinations of factors leading up to a collision.

In order to understand all the causes of a collision, there must be a complete data-gathering, collision investigation. Some investigations fail to identify the correct cause. Others compound this shortcoming by failing to focus on all causes. These failures derive from a number of issues:

- Lack of a systematic/analytical approach – sloppy investigation

- Not getting the data and facts

- Lack of motivation –nobody cares

- Poor communications and cooperation

    - inter-department and stakeholder
    - cross-department

- Rushing; not enough time; being rushed

- Looking for the obvious cause (s)

Finally, concerning collision causes, it must be recognized that fallibility is part of the human condition. The railroad industry cannot change the human condition. However, the conditions under which its employees work can change. The challenge is to find the latent and organizational conditions leading up to a collision. The key to human factor collision prevention is accurate, timely, and unbiased determination of the root causes, and the implementation of targeted corrective actions.

5. FINDINGS, DISCUSSIONS, AND RECOMMENDATIONS

5.1 Introduction

The Findings, Discussions, and Recommendations in this section are based solely on the review and analyses of 65 main-track train collisions occurring from 1997 through 2002. CAWG did not consider results of other investigations, reviews, and analyses of main-track train, or other types of collisions. CAWG results are specific to its data.

After reviewing 65 collision cases, CAWG found situations increasing the risk of a collision. In order to prevent future main-track train collisions of a similar type, CAWG wants the railroad industry to be aware of these situations. As mentioned in the Descriptive Overview section, mechanical and signal failures are generally not involved; nor are degraded weather conditions, or drugs and alcohol.

Findings and recommendations in this study apply to main-track train collisions and not to yard, highway-rail, or switching operation collisions.

5.2 Crew Composition and Experience

Findings and Discussion: Crew Composition and Experience
For freight trains, the conductor and engineer work as a team. One member points out situations that may have escaped the other's attention. In theory, this team concept should prevent collisions, but on occasion, collisions do occur. It is interesting to note of the six Amtrak collisions in this study, four involved one person in the locomotive cab. Two of four cases (CAWG Nos. 2 and 44) may have been avoided if a second crew member was present in the cab. A third collision (CAWG No. 3) possibly could have been avoided with an additional member. In all three cases (CAWG Nos. 2, 3, and 44) the engineer was not asleep. CAWG found, in fact, extraneous circumstances played a role in these three cases.

Table 5-1 shows the years of experience for conductors of violating freight trains and non-violating freight trains. In Table 5-1, the non-violating trains form a basis for comparing experience levels. Based on a small sample of 33 trains, an estimate of the percentage of conductors who have experience between 7 and 22 years is 21.2 percent. CAWG has surveyed other industry sources that suggest the percentage of conductors (road and yard) in this experience range could be as high as 42 percent.

Conductors with 7 to 22 years experience were not crew members of any violating trains. This suggests conductors in this experience range fulfill their role as additional safeguards in preventing collisions of the CAWG's criteria type.

Table 5-1. Conductor Experiences: Violating and Non-Violating Trains

	Violating Train		Non-Violating Train	
Experience	**Number**	**Percent**	**Number**	**Percent**
Under 7 years	20	48.8	15	45.5
7-22 years	0	0.0	7	21.2
over 22 years	21	51.2	11	33.3
Total*	41	100.0%	33	100.0%

***** Conductor experience information was not available in all 65 collisions. More experience was available for conductors of violating (62 percent) than non-violating (51 percent) trains.

CAWG used two statistic tests to compare the difference in proportions (0.0 percent v. 21.2 percent) for conductor experience between 7 and 22 years between the violating and non-violating trains. If appropriate statistical tests are used, adjustment is made for small sample size. Both tests indicate the difference in conductor experience between violating and non-violating trains is significant at the 95 percent level.[25] While significant, CAWG expresses a general caution in interpreting statistical tests of findings from any investigatory studies.[26]

Note: Conductors with fewer than 7 years of experience were involved in 48.8 percent of the collisions, very close to the baseline percentage of 45.5 percent for the non-violators (control group). This difference is not statistically significant.[27] CAWG cannot conclude conductors in this experience group present an unacceptable risk.

However, when both the engineer's and conductor's combined experience is under 5 five years, the level of risk increases, as Table 5-2 indicates.

[25] First test: Z-value of 3.10 was calculated using the standard Difference between Two Proportions test (0.0 percent v. 21.2 percent). P-value = 0.0019, two-tailed test. Second test: An exact Difference between Two Proportions test, more appropriate for smaller samples and proportions than the first test, resulted in a p-value = 0.0024 after the first iteration.

[26] If enough statistical tests are applied to differences uncovered during an investigatory study, 'statistical significances' can result simply by chance. At the 95 percent level of significance, 1 in 20 tests could indicate 'statistical significance' just by chance. For this reason, CAWG limited the number of statistical tests it applied. Additionally, caution is advised in applying statistical tests to investigatory studies because both discovery and proof is being attempted on the same information (data).

[27] A Difference between Two Proportions test was performed. The Z-value was not significant at the 95 percent level.

Table 5-2. Total Crew (Engineer and Conductor) Experience

	Violating Train		Non-Violating Train	
Experience	**Number**	**Percent**	**Number**	**Percent**
under 5 years	11	27.5	2	6.9
5-35 years	13	32.5	17	58.6
over 35 years	16	40.0	10	34.5
Total*	40	100.0%	29	100.0%

* Engineer and conductor experience was not available in all 65 collisions. More experience was available for engineers and conductors of violating (61 percent) than non-violating (45 percent) trains.

Violating train crews, where combined engineer and conductor experience is under 5 years, are involved in 27.5 percent of the collisions compared to 6.9 percent for the non-violating crews (control group). Using the same two statistical tests as applied to conductors with 7 to 22 years of experience, this difference is statistically significant at the 95 percent level.[28]

Five of the eleven cases where crews had less than 5 years of experience involve PCF H989 – *Lack of skill or practical wisdom gained by personal knowledge or action*. (See page 55 for definition of *PCF*.) These crews, with under 5 years total experience, account for almost half of the H989s used in coding the PCFs of the 40 violating trains for which engineer and conductor experience is available. Table 5-3 shows the indicators of inexperience.

Table 5-3. Indicators of Crew Inexperience in Five Main-Track Train Collisions

CAWG No.	Location	Indicators of Inexperience
4	Alvord, TX	Crew did not recognize there was a brake pipe obstruction.
6	Lagro, IN	Crew was relatively unfamiliar with the territory.
8	North Bay, CA	Train exceeded restricted speed and the conductor failed to question the engineer.
9	Wickes, AR	Crew was relatively unfamiliar with the territory.
42	Ransom, IL	Conductor did not take independent action to stop the train.

[28] First test: Z-value of 2.16 was calculated using a standard Difference between Two Proportions test (27.5 percent v. 6.9 percent). P-value = 0.031, two-tailed test. Second test: An exact Difference between Two Proportions test, more appropriate for smaller samples and proportions than the first test, resulted in a p-value = 0.0243 after the first iteration.

Table 5-4 suggests pairing an experienced crew member with an inexperienced crew member does not increase risk for the experienced crew member. Crews with an experience difference over 20 years are involved in 17.5 percent of the collisions, almost the same as the baseline percentage of 17.2 percent for the non-violating crews (control group).

Table 5-4. Experience Difference Among Crew Members

	Violating Train		Non-Violating Train	
Experience Difference Between Crew Members	**Number**	**Percent**	**Number**	**Percent**
Under 3 years	17	42.5	11	37.9
3-20 years	16	40.0	13	44.8
over 20 years	7	17.5	5	17.3
total	40	100.0%	29	100.0%

Recommendation: Crew Composition and Experience
CAWG cannot conclude conductors with fewer than seven years experience are at a higher risk. However, when possible, an inexperienced crew member should be paired with an experienced crew member. Such pairing reduces the risk for the inexperienced crew member; but does not, as CAWG collision cases show in Table 5-4, increase the risk for the experienced crew member.

5.3 Alertness

The methodology employed by CAWG in studying alertness included: (1) defining alertness, for purposes of railroad operations, as to whether or not any action was taken; (2) examining available information concerning each crew member's sleep history, sleep period, work period, and time of event; and (3) consulting a sleep expert to independently evaluate CAWG's assessment of cases involving alertness.

After completing its review of each collision case, CAWG found that 19 of 65 cases – nearly 30 percent – involved alertness as a PCF.

Findings and Discussion: Alertness
Research indicates that degradation of employee alertness can lead to lapses in attention, slowed reactions, and impaired reasoning and decision-making that have been shown to contribute to accidents, incidents and errors in a host of industrial and military settings.

Collectively, these effects have been described as 'fatigue' or 'impaired alertness'. CAWG adopted a data driven approach that focuses on observable behaviors of alertness, i.e., attention to and appropriate responses to one's surroundings rather than the less exact term *fatigue* that has various meanings for different people. Some collisions appear to reflect impaired alertness since appropriate actions were not taken. Impaired alertness may be traced to a number of variables. Here the focus is on two main *causes*:

- Amount of sleep a person has had in the recent past
- Time of day

Many sleep experts believe the average person should obtain about eight hours of sleep per day to maintain peak alertness. Sleep induced impairments in alertness fall into two main categories. The first kind of problem occurs when a person does not get sufficient amounts of sleep each day, extending over a series of days. This produces what is called a sleep debt, a difference between the average amount of sleep actually obtained and the amount of sleep the person needs to maintain alertness. This may be caused by a number of factors including, but not limited to, problems obtaining sleep during off duty time (trying to sleep during the day or in an unfavorable environment), excessive work and associated work demands, such as commuting. Such chronic sleep debt factors may limit the amount of time to get sleep, compromise the quality of sleep or involved sleep disorder, such as sleep apnea. All of these factors can cause an accumulated sleep debt that can impair alertness.

The second kind of sleep problem occurs when a person has been awake more than sixteen hours since their last major sleep episode, called acute sleep debt. Ideally, people sleep eight hours a day and are awake for sixteen hours. Once the awake period exceeds sixteen hours, there is increasing pressure to go to sleep, which is reflected as a gradual loss of alertness and an increased potential for lapses. Problems from acute sleep debt can occur even when a person has been generally getting eight hours of sleep per day. A classic example of acute sleep debt can occur when a person awakens in the morning at 6 am after sleeping regularly from 10 pm to 6 am and does not take any naps prior to going to work in the evening. If work starts twelve hours after awakening and the work period is eight hours long, the person will have been awake for twenty hours at the end of the shift and may experience an acute impairment of alertness during the last half of the work period.

The time of day can induce problems with alertness because the human body has a biological rhythm that modulates alertness. People who are adjusted to day-time work are generally most alert during the hours from 8 am to 8 pm and experience impaired alertness between midnight and 6 am. This is called the circadian rhythm and is a property of many biological systems, including the brain. The exact timing of the rhythm can be changed by environmental factors. For example, when traveling to a new time zone, it can take many days for the rhythm to realign to the new time for sleep and wakefulness. If a person shifts from a day job to a night job, requiring sleep during the day, it may take many days or weeks for that person to adjust to that new routine. During the period of adjustment, the person will experience impaired alertness.

The two causes of impairments to alertness – sleep debt and time of day – are additive. A person working at four in the morning will be more impaired if also sleep deprived compared to a person at that same time who has been getting plenty of sleep and has been awake for only a few hours.

In summary, there are a number of variables that can impair alertness: chronic sleep debt, hours since awakening, and time of day. To determine the level of alertness impairment a crew member might experience, CAWG gathered evidence from numerous sources, including witness statements and interviews, event recorder data, and available work/rest histories of the crews. CAWG reviewed and analyzed each crew member's sleep history, sleep periods, work periods, and time of event.

After completing its review of each collision case, CAWG found that 19 of 65 cases – nearly 30 percent – involved alertness as a PCF. Realizing the importance of the alertness issue, CAWG asked Dr. Stephen Hursh, a sleep expert already working for FRA, to independently review CAWG's findings concerning each of the 19 cases. Material reviewed by Dr. Hursh originated from Federal Railroad Administration investigations, and in some cases National Transportation Safety Board investigations. CAWG then compared his alertness assessment with that of its independent findings, the result being that CAWG's methodology was determined sound.

There are several general patterns of work and sleep history. Nearly all the collisions that had an alertness component occurred between midnight and eight in the morning. Hence, they all involved a circadian component.

Alertness Scenario #1

Scenario #1 (Table 5-5) would seldom be described as *fatigue* in the usual sense of the word. An employee had one or more days off prior to the day of the collision. There was ample opportunity for the employee to obtain at least eight hours of sleep on the day prior to the collision. But the work period started in evening and extended into the early morning hours. The call to work may have been unexpected; and, the likelihood is low the employee took an evening nap in preparation for work. As a result of this pattern, the employee experienced the combined effects of poor time of day and acute sleep debt (long hours since awakening).

Table 5-5. Alertness Scenario #1

CAWG No.	Location
1	Kenefick,
2	Jacksonville
19	Momence
32	Perkins
45	Wendover
59	North Platte
62	Vader (engineer)
65	Valley Pass

Alertness Scenario #2

Scenario #2 (Table 5-6) involves an employee's accumulated sleep debt that is the result of having either limited opportunity to sleep or to sleep only during day light hours. Usually the event occurs immediately after a day in which the available time to sleep is unfavorable for restorative sleep, perhaps combined with a chronic sleep debt, and with an unfavorable time of day. To document accumulated sleep debt in this scenario, a detailed, long-term work/rest record is required.

Table 5-6. Alertness Scenario #2

CAWG No.	Location
62	Vader (conductor)
64	Des Plaines (engineer)

Alertness Scenario #3

Scenario #3 (Table 5-7) is similar to Scenario #2. Here, there is no evidence of accumulated sleep debt over many days, but there were two work periods in a single 24-hour period and the opportunity to sleep immediately preceding the work period of the collision was in the afternoon hours when sleep is most difficult to achieve. As in the other scenarios, the work period extends into the early morning hours so this acute sleep deficit combines with an unfavorable time of day.

Table 5-7. Alertness Scenario #3

CAWG No.	Location
15	Butler
21	Palm Springs
34	Wickes
49	Pacific

Alertness Scenario #4

Scenario #4 (Table 5-8) contains five cases. These cases include medical (e.g. sleep disorders) and other issues that adversely affected the employee's alertness.

Table 5-8. Alertness Scenario #4

CAWG No.	Location
12	Navasota
38	Racine
44	Hallsville
46	Andersonville
51	Bradford

Alertness Scenario #5

Four of the 19 cases involved impaired alertness factors, but the collected data did not support inclusion into any of the above scenarios. These cases are shown in Table 5-9.

Table 5-9. Alertness Scenario #5

CAWG No.	Location
6	Largo
21	Palm Springs
50	Kenner
64	Des Planes (conductor)

The collision at Largo (No. 6) was reviewed and compared to the criteria used to classify the other twenty-one cases into one or more of the five alertness scenarios presented above. CAWG was unable, however, to conclusively classify this case as an alertness issue.

Recommendation: Alertness
CAWG makes several general observations suggesting avenues for improvements in railroad industry habits and procedures to reduce the incidence of impaired alertness. First, working between midnight and 8 am is an operational necessity that entails an operational risk. This risk needs to be further recognized and countered by the railroad industry. The circadian impairment in alertness that occurs at this time of day is a biological fact. No amount of training, conditioning, or motivation can eliminate the risk of lapses in attention that can occur at these hours. Procedural innovations should be devised to create redundancy and error checking to counter this natural phenomenon.

CAWG believes adequate sleep leading up to night work and napping immediately prior to a night shift are important countermeasures for minimizing the effects of the circadian reduction in alertness occurring between midnight and 8 am. Getting this sleep is a shared responsibility of employees and management. The employees must be trained and encouraged to:

- Understand the importance of adequate sleep and good sleep hygiene.
- Make personal decisions to incorporate evening naps into their daily routines.
- Plan activities so sleep is properly timed to minimize both chronic and acute sleep debt.

Management has a major role in enabling these behaviors. Unexpected or unplanned calls to work in the evening make it difficult for employees to take naps in anticipation of an evening call. It is unrealistic to expect employees to take naps in the evening when the family is at home unless there is a reasonable expectation they will be called to work. In short, evening calls for night work should be as predictable as possible. An unexpected call in the morning for a day shift is almost never a problem for alertness because it usually follows a night of sleep and coincides with the up-swing in normal circadian alertness. Unexpected calls in the evening are precisely the opposite; the person has already been awake for ten to twelve hours and will experience acute sleep debt. The work shift will coincide with the down-swing in circadian alertness. Operational procedures that increase the predictability of evening and night calls make it possible for employees to take necessary naps that minimize impairments to night-time alertness.

5.4 Intra-crew Communication

Findings and Discussion: Intra-crew Communication
CAWG examined the interviews conducted and data reported for the crews, attempting to document each individual's performance of assigned duties during the time previous to the collision when track authority was exceeded and up to the actual impact, noting whether the crew member stayed aboard or jumped.

CAWG experienced a wide variance in the number, extent, and completeness of written statements in the interview files. CAWG focused on factual content of data and interviews addressing individual performance of assigned duties. CAWG initially identified forty-two cases from reviewing the completed CAWG Matrix, using the perspectives defined in situations #1 through #4, shown in Table 5-10. CAWG reviewed each of the forty-two cases, establishing consensus on the ten cases that potential lack of proper intra-crew communication may have been a possible contributing factor to the collision. CAWG also focused on what could have prevented the collision and what recommendation would facilitate safety of operations by the train crew members.

Table 5-10. Intra-crew Communication

CAWG No.	Location	Situation			
		#1	**#2**	**#3**	**#4**
5	Hummelstown, Pennsylvania	X			
6	Largo, Indiana		X		
8	North Bay, California		X		
15	Butler, Indiana	X	X		
16	Creston, Iowa				X
17	Orin, Wyoming		X		
20	Mount Pleasant, Texas			X	X
31	Woodburn, Iowa	X			
51	Bradford, Illinois	X	X		
55	Clarendon, Texas	X			
10 cases	totals	5	5	1	2

Situation #1: Cases with Possible Contributing Factor (PCF) H316, *Poor intra-crew communications*.

Situation #2: Cases with PCF H989, *Lack of skill or practical wisdom gained by personal knowledge or action*.

Situation #3: Cases with PCF H215, *Block signal, failure to comply*; PCF H216, *Interlocking signal, failure to comply*; PCF H605, F*ailure to comply with restricted speed*.

Situation #4: Cases where crew of probable violator was not performing duties during the time previous to the collision when track authority was exceeded.

Recommendation: Intra-crew Communication
When there are two or more train and engine service employees in the cab of a locomotive, there should be an established process to ensure that every wayside signal, directive, instruction, and order is clearly and completely understood and properly executed by every crew member. Other activities must not interfere with the safe

operation of the train. Particular attention to movement authority is needed when trains meet, one train overtakes another train, or when train operations occur in the vicinity of yards or industries where other train movements take place. There are ongoing crew resource management efforts.[29]

5.5 High-Risk Holiday Periods

Findings and Discussion: High-Risk Holiday Periods

While main-track train collisions have occurred at any time of year, based on the 65 collisions reviewed by CAWG, there are two high-risk periods for main-track train collisions:

- One week period bracketing Independence Day (July 4th.).
- Three-week period bracketing Christmas (December 25th) and New Year's Day (January 1).

As shown in Table 5-11 in the six-year period 1997 through 2002, there were 10 collisions during the four-week (per year) holiday period. This exposure over the six-year period equals 24 weeks (6 x 4). Ten collisions over 24 weeks is an incidence risk of 0.42 collisions per week (10 / 24 = 0.42). The remaining 55 collisions occurring over the complementary six-year, 288-week period (6 x [52 – 4]) corresponds to an incidence risk of 0.19 (55 / 288 = 0.19). The relative risk (RR) for the four-week holiday period is 2.21 (RR = 0.42 / 0.19). A statistical test applied to the differences in incidence risk indicated significance at the 95 percent level.[30]

Reasons for the increased risk are not apparent from the review of the 65 main-track train collisions. If train traffic is reduced during the two holiday periods above, then the increase in risk during these four-weeks is more dramatic. Three other holiday periods – Memorial Day, Labor Day, and Thanksgiving – were not found to be at higher risk.

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[29] The FRA's Human Factors Research Program and the Office of Safety have jointly sponsored an extensive program of research and development on crew resource management (CRM) training in the railroad industry. The CRM program has four components: 1) a review of CRM training methods, the types of teams found in the railroad industry, and the matching of team types with the most appropriate CRM training methods; 2) the development of curricula appropriate for CRM training for crews in transportation crafts (locomotive engineers, conductors, dispatchers, switchmen, brakemen), engineering crafts (MOW, signal maintainers, electrical catenary crews), and mechanical crafts (machinists, electricians, pipe fitters, carmen); 3) the implementation and evaluation of a pilot training program at a Class I railroad; and 4) the development of a business case for CRM training in the railroad industry.

Reports on the components of the CRM program are under review and will be posted on the FRA website when approved for publication. In addition to these reports, training course materials for the transportation, engineering and mechanical crafts will also be available.

[30] Chi-square (χ) = 6.82 with a p-value = 0.009. The 95 percent confidence interval for the RR is 1.28 to 3.71, a range excluding the relative risk (RR) null value of 1.00.

Table 5-11. Four High-Risk Weeks for Main-Track Train Collisions, 1997 through 2002

High-Risk Weeks: One week surrounding Independence Day; and three weeks surrounding Christmas and New Year's Day

	Four High-Risk Weeks	Forty-Eight Other Weeks
Collisions	10	55
Number of weeks	24	288
Collisions per week	0.42	0.19

Fatalities and injuries occur in main-track train collisions. Thus, there is also a risk for increased casualty to train crew members. The risk for these four weeks compared to the risk of all other weeks (Table 5-12) is 1.33 v. 0.41, a relative risk of 3.24 (RR = 1.33 / 0.41 = 3.24).

Table 5-12. Four High-Risk Weeks for Employee Casualties in Main-Track Train Collisions, 1997 through 2002

High-Risk Weeks: One week surrounding Independence Day; and three weeks surrounding Christmas and New Year's Day

	Four High-Risk Weeks	Forty-Eight Other Weeks
Fatalities and injuries	32	119
Number of weeks	24	288
Casualties per week	1.33	0.41

The SOFA Working Group (SWG) found a similar high-risk period existed in its review of 124 switching fatalities occurring, 1992 through 2003. The risk for these four weeks compared to the risk of all other weeks (Table 5-13) is 0.31 v. 0.19, a relative risk of 1.63 (RR = 0.36 / 0.16 = 1.63). SWG, too, could not find an explanation based on review data developed from FRA investigations.

Table 5-13. Switching Fatalities, January 1992 through December 2003

High-Risk Weeks: One week surrounding Independence Day; and three weeks surrounding Christmas and New Year's Day

	Four High-Risk Weeks	Forty-Eight Other Weeks
Switching fatalities	15	109
Number of weeks*	*48	**576
Fatalities per week	0.31	0.19

*   number of high risk weeks = 12 years multiplied by 4 weeks/year.
** number of other weeks = 12 years multiplied by 48 weeks/year.

Recommendation: High-Risk Holiday Periods
The potential exists for the industry to better understand the reasons for the high-risk periods for main-track train collisions. Identifying the reasons could bring opportunities for prevention. Studies directed towards understanding should be undertaken. These studies need not be specific to main-track train collisions. Studies could include all human-factor related undesirable outcomes including collisions and employee casualties. These findings may identify and reduce risk during holiday periods.

The industry should alert employees to the increased risk during these periods.

5.6 End of Train Devices (EOT), *49 CFR Part 232, Subpart E*

Findings and Discussion: End of Train Devices (EOT)
CAWG could find little evidence of testing and data collection on the effects of EOT activation in emergency train brake applications. How much stopping distance was actually saved by simultaneous application of the EOT? Obviously, train speed effects distance in feet. CAWG wonders whether it is proportional for speed, or if the percent benefit in stopping distance saved is greater for higher train speeds. CAWG conducted a literary search for industry data on any available research and testing on this issue. CAWG was unable to establish any definitive research or studies.

CAWG canvassed the railroad industry with little success. A few railroads responded with experience, mostly anecdotal that with the existing train brake system, "The automated feature for the 2-way valve on the rear of the train has minimal affect on stopping distance. If the emergency application actually occurred simultaneously at both ends of the train (as simulations we performed were done to evaluate this issue) stopping distance is improved approximately 10 percent."

Recommendation: End of Train Devices, 49 CFR Part 232, Subpart E
Training programs should be created, conducted, and documented on a continuing regular basis to ensure engineers are able to instinctively activate the EOT when the train brakes are put into emergency. CAWG suspects that junior engineers are probably made aware and qualified during their training. More senior engineers are of greater concern to CAWG, since instruction and review of the practice must overcome years of experience without a two way EOT to activate. This shortcoming potential for more senior engineers may manifest itself under time-critical performance of operational duties. EOT training should be included in locomotive engineer evaluations and, when possible, in rule efficiency checks. Training should also include train crew awareness of whether or not the locomotive in the lead that they are operating will activate the EOT automatically; or whether it requires manual activation. This question becomes critical as more of the new locomotives come on line.

All locomotives ordered on or after August 1, 2001, or placed in service for the first time on or after August 1, 2003, shall be designed to automatically activate the two-way, end-of-train device to effectuate an emergency brake application whenever it becomes necessary for the locomotive engineer to place the train's air brakes in emergency. [from 49CFR Part 232.405(f)][31]

Data driven simulation and actual research should be conducted and published for the railroad industry, and train crews in particular, to clearly understand the impact and importance of this issue; and the effects of EOT activation when the train brake is placed in emergency from the lead locomotive.

5.7 Crashworthiness

Findings and Discussion: Crashworthiness
Locomotive crashworthiness is important to the survivability of locomotive crews given that a collision has occurred. The intent of CAWG was not to determine the crashworthiness of various locomotives, or the advisability of crews staying in, or jumping from, the locomotive given collision certainty. However, from the review and analysis of the 65 collision cases, information was generated of likely interest to those engaged in locomotive crashworthiness. CAWG wants to make those interests aware of this information now contained in the CAWG Database.

Some analysis, however, was performed. Logistic regression was used to analyze the risk of injury and fatality in collisions from the decision to jump from, or stay in, the locomotive. This multivariate technique controls for confounding variables while testing the effect of interest – whether the employee's decisions to exit or stay, given collision certainty, changed the risk of injury or fatality. Factors controlled for affecting the risk were: train speed, collision type, whether the locomotive was built to S-580 standards. The current S-580 standards are contained in the Appendix. CAWG again stresses that

[31] During the 1990s, prior to this requirement, several railroads had initiated this practice.

crashworthiness was not a study purpose, and its review and analytical methods did not include a study design to best capture crashworthiness information.

The analysis produced the following results:

- The probability of injury was greatly affected by the decision to exit or stay with the locomotive. Eighty-seven percent of employees who exited the locomotive were injured compared to 51 percent who stayed with the locomotive.

- There was no significant indication in the data that the decision to exit or stay with the locomotive changed the likelihood of fatality. The probability of a fatality was greatly affected by train speed.

Recommendation: Crashworthiness
CAWG suggests that future groups studying crashworthiness may find our efforts of some use as a baseline point as enhanced safety equipment and changes brought on by the continued development of S-580 standards. (Refer to Federal Railroad Administration's (FRA's) Website for existing crashworthiness studies.[32])

5.8 Operating Methods

Findings and Discussion: Operating Methods
CAWG compared collisions occurring in Traffic Control System (TCS) territory to those occurring in train order territory[33] (e.g. track warrant territory). The purpose of the comparison was to determine whether the number of collisions per million train miles are different in one type of territory versus another. The comparison was difficult to conduct because the current accident reporting form does not have a consistent process of reporting methods of operations. (See the finding on accident reporting below.)

After considerable review and discussion, CAWG was able to determine the method of operation for all collisions. Table 5-14 shows 45 CAWG collisions in TCS territory and 12 collisions for train order territory.[34] The remaining 8 collisions occurred in other situations.

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[32] On Federal Railroad Administration's (FRA's) Website: Click on 'Research and Development', then 'Research Reports'. Studies include DOT/FRA/ORD-02/03, DOT/FRA/ORD-01/23, DOT/FRA/ORD-95/08, and DOT/FRA/ORD-95/08I through 95/08V.

[33] *Train order territory* is defined herein as territory within which written authority is required for train movements.

[34] Again mentioned, *train order territory* is defined herein as territory within which written authority is required for train movements.

Table 5-14. Collisions by Territory Type

Territories from Volpe Center Study	Train Miles from Volpe Center Study	CAWG Collisions	Collisions per million Train Miles
Auto	44,220,891	6	
CTC	300,580,358	39	
Total for TCS	**344,801,249**	**45**	0.131
ABS	80,773,696	8	
Dark	58,600,600	4	
Total for Train Orders	**139,374,296**	**12**	0.086
Interlockings, Yard Limits, Form Bs	-----	8	-----

Using estimated train miles by territory from a Volpe Center study,[35] CAWG was able to form an estimated collisions per million train miles for each type of territory. The collision rate for train order territory, 0.086, is not higher than the collision rate, 0.131, for TCS territory. CAWG expected the collision rate for train order territory[36] to be significantly higher than TCS territory, so this is a surprising result. Most expected the additional computer assisted data and information developed with TCS to reduce exposure unique to train order territory, where additional manipulation and oversight by crew members is required; and thus, train order territory would be expected to be subject to additional human failure.

Two study limitations may account for this unexpected result:

- CAWG collisions do not represent all collisions.[37] For example, CAWG selected only those collisions having an FRA HQ investigation number; and from those, collisions where trains exceeded authority. Situations where crews improperly gave up authority, such as misaligning a manual switch, are not covered by CAWG.

[35] *Base Case Risk Assessment: Data Analysis & Tests*. Study done by the John Volpe National Transportation Systems Center for the Office of Safety, Federal Railroad Administration. RSAC/PTC Working Group Risk 2 Team. Updated April 19, 2003.
[36] *Train order territory* is herein defined as territory within which written authority is required for train movements.
[37] The Volpe Center study formed rates by territory from approximately 800 collisions. These collisions were selected based on being preventable by a Level 3 PTC system and having total damages exceeding the FRA's monetary reporting threshold.

- Collisions for 2003 and 2004 are not covered in this report. Adding CAWG collisions for these years could change the estimated collision rates in a significant way.

A PCF profile of the two types of territories sheds light on the different collision rates associated with the two territories (Table 5-15).

Table 5-15. PCFs by Territory Type

Possible Contributing Factor	Definition	Train Order Territory	TCS Territory	Remarks
E03C	Obstructed brake pipe (closed angle cock, ice, etc.)	1		
E03L	Obstructed brake pipe (closed angle cock, ice, etc.) (locomotive)		1	
H101	Impairment of efficiency or judgment because of drugs or alcohol		2	
H104	Employee asleep		8	Note: This PCF only occurred in TCS territory.
H199	Employee physical condition, other (Provide detailed description in narrative		3	
H203	Fixed signal improperly displayed		1	
H204	Fixed signal, failure to comply	2	5	
H211	Radio communication, improper	1		
H212	Radio communication, failure to give/receive		1	
H215	Block signal, failure to comply	4	24	
H216	Interlocking signal, failure to comply		21	
H299	Other signal causes (Provide detailed description in narrative)		1	
H307	Shoving movement, man on or at leading end of movement, failure to control		1	
H316	Poor Intra-crew communication (CAWG only)	4	5	One-third of CAWG collisions in train order territory have this PCF. This is significantly higher than TCS territory.
H317	Failure to communicate unsafe condition		2	
H318	Poor crew utilization	1	4	
H398	Poor Inter-crew communication (CAWG only)	1		
H401	Failure to stop train in clear	1		
H404	Train order, track warrant, track bulletin, or timetable authority, failure	3		
H499	Other main track authority causes (Provide detailed description in narrative	2		
H509	Improper train inspection	1		
H510	Automatic brake, insufficient		1	
H599	Other causes relating to train handling or makeup (Provide detailed description)		1	
H604	Train outside yard limits under clear block, excessive speed		1	
H605	Failure to comply with restricted speed	3	8	
H702	Switch improperly lined	2		
H799	Use of switches, other (Provide detailed description in narrative)	1		
H989	Lack of skill or practical wisdom gained by personal knowledge or action	4	6	
H991	Tampering with safety/protective device(s)		1	
H992	Operation of locomotive by uncertified/unqualified person		1	
H999	Other train operation/human factors	1	5	

	(Provide detailed description in narrative)		
M104	Extreme environmental condition - DENSE FOG		3
M199	Other extreme environmental conditions (Provide detailed description)	1	
S099	Other signal failures (Provide detailed description in narrative)		1

In train order territory, Table 5-15 identifies problems with intra-crew communication in 4 of the 12 cases; this is a significantly higher ratio than the corresponding ratio for TCS of 5 out of 45 cases.

Table 5-15 also shows all collisions where at least one employee was asleep occurred in TCS territory. Table 5-15 indicates alertness is more of a risk factor in this type of territory. The 12 cases in train order territory did not identify any employee being asleep. This risk factor may partially explain why TCS territory does not exhibit a lower CAWG collision rate than train order territory.

Recommendation: Operating Methods
CAWG suggests a potential finding of differences in crew alertness between TCS and train order territory, but does not make a recommendation. Future studies may look at the performance of visual tasks, written communication requirements, and other train crew activities.

5.9 Collision Investigating and Reporting

Findings and Discussion: Collision Investigating and Reporting
<u>Collect Human Factor Data</u>
After reviewing the first 14 collision cases, CAWG decided to rate the quality of the Federal Railroad Administration's investigation as shown in Table 5-16. Seven cases (14 percent) were rated 'very good'; 26 (50 percent), 'good'; 17 (34 percent), 'fair'; and 1 (2.0 percent), 'marginal.'

Table 5-16. Quality Ratings of Main-Track Train Collision Investigations, 1997 through 2002

Number of Cases	Rating	Percent
7	Very Good	14
26	Good	50
17	Fair	34
1	Marginal	2
totals *51		100.0%

* After reviewing 14 collision cases, CAWG decided to rate the investigation quality of the remaining 51 cases.

Those cases rated as either very good or good contained detailed information concerning each employee's work history, experience, training, the level of management oversight, and work/rest histories going back at least 10 days. Those cases rated fair or marginal by CAWG did not contain many of the items listed for various reasons. These findings led CAWG to discussing how FRA conducts a collision investigation, what is required, and why FRA does not, as a rule, investigate and document an employee fatality as the result of a human factors collision with the same level of thoroughness as an employee on duty fatality (FE).

Where human factor issues were not fully developed in cases, CAWG felt that "root cause analysis," with accurate conclusions and beneficial recommendations, could not always be clearly established. However, since the end of the CAWG study period (2002) additional training has been provided for FRA Inspector forces; and regional management has been re-trained on Accident/Incident Investigation Review. This effort, along with personnel changes at FRA's Accident Analysis Branch have led, in many cases, to a more comprehensive and standardized final report, particularly over the last four years. Additionally, the FRA and some railroads are in the process of developing new human factor tools that have the potential to be useful when applied to accident/incident investigation.

Recommendation: Collision Investigating and Reporting
<u>Collect Human Factor Data</u>
FRA should identify and document all relevant human factor data. This data includes crew members' experience on the territory where the collision occurred, their age, experience in craft, and railroad seniority of each of the crew members in the collision (striking and struck crews). A work/rest history that clearly indicates off and on-duty times for both train crews and accompanying paperwork on how off duty time was spent, if possible, should go back a minimum of 10 days. CAWG recommends a review of management oversight for all of the violating train crew-members. The oversight should

include training results and a review of the number of efficiency tests performed on each crew member during the last 6 months, the number directly related to the incident and the number of tests passed and failed.

Findings and Discussion: Collision Investigating and Reporting
<u>Update CAWG Database</u>
The experience gained by the Switching Operations Fatality Analysis (SOFA) Working Group (SWG) development and analysis of a data matrix was valuable to the CAWG's work and endeavors. The SWG entered detailed information on the 76 switching fatalities upon which its October 1999 [38] study was based, into a Microsoft® Excel spreadsheet. By continuing to review and add switching fatalities to its 'SOFA Matrix', the SWG created retrievable, electronic records of 124 fatalities. Integrating the information on the additional 48 switching fatalities with that of the original 76 fatalities allowed the SWG to further identify additional operational exposures to fatalities, in the form of Special Switching Hazards, to employees engaged in switching operations. CAWG would benefit from additional case analysis.

Recommendation: Collision Investigating and Reporting
<u>Update CAWG Database</u>
The CAWG Database allows for quick retrieval and querying of information on the 65 main-track train collisions occurring from 1997 through 2002. CAWG recommends that its Database be updated for 2003 and 2004 collisions meeting the established criteria. Additional years of information will allow for up-to-date querying to determine present risk factors and commonalities with past collision events.

Findings and Discussion: Collision Investigating and Reporting
<u>Reporting Signal Information</u>
CAWG notes that some collisions occurred in territory where the transiting train encountered the sequence GREEN, YELLOW, RED. CAWG considered the benefit of a fourth signal: FLASHING YELLOW, or two consecutive YELLOWs, giving a greater advanced warning time to an absolute stop signal. Changes in the configuration of existing signals may have provided beneficial results to safe operations in some of the collisions reviewed. However, the data files, which CAWG had available and reviewed, did not contain sufficient data and information on signal systems to establish and/or evaluate. Therefore, CAWG could not make a determination about the collision-prevention value, if any, of a four- signal sequence as opposed to a three.

Many cases contain information about crew members' perceptions of signal aspects prior to a collision. This information was derived from testimonies taken from those affected during post-collision interviews. Given that Distant Signals (the signal preceding a Home Signal) are not routinely equipped with recording devices and therefore cannot create a record of what aspect the Distant Signal was displaying, the investigation regarding specific signal aspects preceding the collision is based upon the testimonies of carrier officials, affected train crew members, signal tests that have been performed on the

[38] *Findings and Recommendations of the SOFA Working Group*. October 1999.

signals in question and information gleaned from data and event recorders at the Control Point or Interlocking where the collision took place. When these tests and signal reports contradict the crew member's testimony, it is assumed that the crew member did not correctly remember the signal indication. It appears that at times, detailed information on signal issues is not identified, collected, documented, and reported. Until this information is systematically collected, a system wide database cannot be developed capable of being queried regarding the number of collisions occurring in three signal-sequence territory, as opposed to the number occurring in territory equipped with a four sequence-system. Without this level of relevant information and data, CAWG believes that future working groups will be unable to establish specific conclusions and effect meaningful safety improvements.

Recommendation: Collision Investigating and Reporting
<u>Reporting Signal Information</u>
In an effort to build a reliable data base, CAWG recommends that reporting of post incident testing involving signal systems include information on the type of signal system, model number of signal apparatus, and aspects from each signal. Aspect information should be gathered from an adequate number of signals to clearly identify all those relevant to the incident. Signal apparatus information should include the type and number of heads located on each signal mast.

Finding and Discussion: Collision Investigating and Reporting
<u>Reporting Method of Operations</u>
CAWG found inconsistencies regarding the entries made to field number 30 (Methods of Operation) on form *FRA F6180.39* used by FRA Investigators to record objective data about the accident they are investigating. Often, commingling signal authority with safety overlays. For instance, a train operating in Traffic Control System (TCS) territory will also be governed by automatic block signals; therefore, it is redundant to use both the "e" and the "g" codes. Further, the practical difference between "I"-Timetable/train order, "j"-Track warrant, and "k"-Direct traffic control is negligible when annotating a block used to indicate a "method of operation" and could certainly be spelled out later on in the report if necessary to clarify why the accident occurred as the result of one of these methods of operation and may not have happened using another.

CAWG invested considerable effort to convert the reported codes into a framework that was useful for analysis.

Recommendation: Collision Investigating and Reporting
<u>Reporting Method of Operations</u>
FRA should review block 30 on the most recent form *FRA F6180.39* (Revised July 2003) and determine which methods of operation belong in the block, which methods of operation should be combined, and which methods should be removed. CAWG believes FRA would create a more standardized and efficient way of sorting on the method of operation in effect at the time of the incident.

EPILOGUE

Only in its Epilogue have CAWG members consciously offered interpretations based on their railroad experience. Such is the purpose of an epilogue. The body of a report contains factual, data-based information. An epilogue allows authors more leeway in drawing upon their experiences in interpreting data-based information.

The railroad industry is making substantial progress reducing incidents. Many of the easily identified and understandable causes – track and mechanical – are being addressed and dangerous exposures substantially reduced or eliminated.

However, over the past ten years, the industry found no clear and identifiable trend of improvement in human-factor related collisions. Review of the 65 collisions comprising this study established that many of these events were a combination of unrelated factors and deviations occurring at the same time, at the same location, and on the same train. Sometimes, these factors and deviations do not represent a readily identifiable violation of operating regulations and/or standards: the more factors and deviations present, the more likely a collision.

The railroad industry has undergone revolutionary change over the past generation. Deregulation forced railroads to become far more efficient and price-competitive than at any time in their history. These pressures were exacerbated as the U.S. economy increasingly adopted "just-in-time" manufacturing and inventory procedures.

The industry's optimization of capacity and introduction of innovative technologies, which began after World War II, picked up steam in the 1980s. By the turn of the 21st Century, employee headcounts had steeply declined, while the number of Class I railroads dwindled to single-digits and networks of Shortline carriers grew.

The operating employee of today works in a vastly different environment than his or her predecessor. It is marked by unit trains, blocking by destination, replacement of the caboose by end of train devices (EOTs), distributed power, wayside detectors, and various means of auditory and visual communications.

By far the most noticeable change for operating employees has been the reduction of crew size made possible by technology. While error-free job performance by crew members has always been the standard, that mandate is heightened in a reduced crew environment, because the observational redundancy provided by the "eyes and ears" of the third, fourth and fifth crew members no longer exist.

This is not to say that crew size reductions have made the industry less safe. Not only does the dataset not support such a conclusion, the purpose of our review was to investigate why human factor accidents are not trending downward, not because of any increase.

Nevertheless, one important point must be made. The technology enabling the reduction of crew sizes is most adept at detection and documentation of human error. However, some of this technology does not function preventively, as would a warning from a crew member devoting an extra pair of eyes and ears to a task.

Many devices now available need further examination to evaluate their potentials to assist crew members to maintain a fail-safe job performance level. Furthermore, when new technologies are considered and designed, the industry should not lose sight of the totality of the functions being replaced, rather than merely the minimal aspects the technology will assume.

Mergers and "spin offs" during the last twenty years further complicate current methods of train operations. There has been a marked expansion of joint operations, major changes to and expansions of seniority districts, and foreign line train operations on a routine basis. Such complications require that today's road freight crews be qualified on more operating rules and physical characteristics than their predecessors could have imagined, a burden that constantly tests one's situational awareness.

For example, one collision we studied occurred when a foreign line crew failed to understand the correct meaning of a "red, over red, over yellow" signal as "restricted proceed." This mistake may have been made because the meaning on their "home" road was "diverging route approach." In another case a home signal imperfectly displayed, should be understood as a "stop." The experienced crew failed to understand that the signal they thought they observed (diverging route approach) could not be displayed at this geographic location. Although these examples are isolated, and somewhat rare, they point to the need to include situational awareness as a factor when changes to operations are being considered.

The composition of the general population from which operating employees are being hired is different than previous generations. New employees in the railroad industry have different interests, abilities, and skills than their predecessors. New railroad employees entering the work force today are more computer literate. Adolescent activities and learning processes of many new railroad employees were based on electronic and computer fundamentals.

An unique opportunity exists to tap into these skills to improve training and abilities. New methods should be developed to exploit their potential. It is easier to use potential skills to jump-start understanding of complex processes for relatively new employees. Such new methods, when implemented, could further improve safety of operations. Although education and training have a constant impact on job performance, however, they cannot substitute for on-the-job experience.

In this regard, it might be tempting to point to downsizing, outsourcing, attrition, and retirements as the cause of a drain in railroad industry knowledge levels, and stagnating human factor accident rates. The reality is much more sophisticated than that simple overview. Better training and tools should become the cornerstone for modern collision investigation and implementation of safety improvements, and we believe that a clear mandate exists to improve investigation techniques.

The cases studied demonstrate that a measurable benefit to safety can be realized from meaningful assessment of the overall processes of train movements in main track operations. While there is much commonality in the operating rules across America's railroads, there also is much divergence. Each railroad has developed its own system of rules and procedures to reflect the geographic, climatic, shipper, and cultural base unique to it, and numerous rules are grounded in a particularly tragic or catastrophic event a railroad endured. In some cases, implementation of rules and procedures over the years have established standards and processes that are more complicated than required, especially for new and relatively inexperienced employees.

Thus, when a detailed study of accidents is undertaken, it is natural to inquire whether – and to what extent – a particular railroad's unique "operating culture" was related to an accident. Any examination and evaluation of the overall process of train operations must be inclusive of all possible elements and parameters.

Some past investigative efforts were piecemeal, and assumed existing methods of train operations to be inviolate and immutable. Others limited themselves to regional or seniority district boundaries. Better results may be possible when these arbitrary barriers are broken down and novel solutions are considered and implemented.

Unfortunately, these changes in culture occasionally involve shifts in authority and "new ways" of operating. It is easy to argue against such initiatives, and the interests of various industry stakeholders are going to be different. However, all stakeholders must seek common ground, and compromises are both necessary and inevitable. It will take time to successfully implement resulting methods, standards, and processes. There must be a total commitment by all stakeholders for successful implementation of significant changes, with enhanced safety being the commonly shared goal.

The railroad industry's greatest challenge has always been to maintain or improve safety while increasing productivity.[39] Everyone wins when railroads move more freight and do it safely. However, operating employees are under more pressure than their predecessors to fulfill demand for greater productivity. Those men and women have answered the call, and the productivity of the contemporary operating employee is truly remarkable.

Nevertheless, so long as trains move by the grant of authority from wayside signals, written communications, or verbal directives perceived, received, and acted upon by human beings, the greatest influences on railroad safety will be the decisions made by the human beings in the control cab of a locomotive.[40] As the industry's technology is poised on the threshold of a new era, it is critical that all stakeholders exercise prudence and care

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39 See chart on Ton Miles/Employee in *Appendix*.

40 As Dekker (2002) says, "People are the only ones who can hold together the patchwork of technologies introduced into their worlds; the only ones who can make it all work in actual practice." (p. 103)

to ensure that technological evolution does not unintentionally erode the significant progress made to date in the safety of railroad operations.